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THE LOWER RAPIDS OF THE MISSISSIPPI RIVER[1]

In the early days of navigation on the Mississippi two important rapids were found to interrupt the passage of vessels at low-water stages; one, about fifteen miles in length, being above the city of Rock Island, Ill., and the other, about eleven miles in length, above the city of Keokuk, Ia. These became known respectively as the upper and lower rapids. The latter are also called the Des Moines Rapids, because of the situation above the mouth of the Des Moines River. In both rapids the obstructions consist of rock ledges, yet the form or arrangement of the ledges is not the same. The upper rapids consist of a succession of rock barriers called "chains," each usually but a fraction of a mile in breadth, which pass across the river channel and are separated by pools or stretches of slack water. The lower rapids are more uniform, there being a nearly continuous descent across them. The rate of descent, however, varies, as shown below. In opening the upper rapids to navigation it was necessary only to cut channels across the barriers, while in the lower rapids a canal has been constructed. This consists of a channel blasted out of the rock for a distance of three and a half miles from the head of the rapids, below which a retaining embankment is built on the river bed along the Iowa side to the foot of the rapids at Keokuk.

The precise length of the lower rapids is 11.1 miles, the head

[1] Read at Thirteenth Meeting of Iowa Acad. Science at Des Moines, December 28, 1898. Published by permission of the Director of United States Geological Survey.

being at Montrose Island and the foot a short distance above the river bridge at Keokuk. The total descent is 22.17 feet, or very nearly two feet per mile. The rate of descent is greatest in the lower part, there being a fall of about 4¼ feet in the lower mile and nearly eight feet in the lower two miles. From Greenleaf's[1] report on "Water Power of the Mississippi and Tributaries," the following data are obtained. "In the first 4800 feet from the lower lock there is a rise of 4.21 feet, then 2.22 feet in the next 3600 feet, and 1.67 feet in the succeeding 3600 feet to the middle lock, making the fall in ordinary low water from a point opposite the middle lock to the foot of the rapids 8.1 feet." Above this part, the fall, though not uniform, is less definitely broken into rapids and pools than in the upper rapids. Indeed, there appears to be a rock floor forming the river bed throughout the entire length of the lower rapids.

Immediately above the head of the lower rapids a deep preglacial channel appears, whose floor, as shown by several borings, is 125 to 135 feet below the low-water level of the river. This is filled mainly with blue bowlder clay up to about the level of the river bed. Sand, however, in places, extends to a depth of nearly sixty feet below the surface of the river at low water, as shown by the bridge soundings at Ft. Madison and Burlington. A pool extends from the head of the rapids up to the vicinity of Ft. Madison, nine miles. The depth of the pool in places exceeds twenty feet at low-water stage, thus extending to about that distance below the level of the rock surface in the river bed at the head of the rapids.

Below the rapids the river for four miles is in a narrow valley, in which the depth of the drift-filling is not known. It there enters a broad preglacial valley, which has been found to constitute the continuation of that occupied by the river above the rapids, and which no doubt was excavated to a corresponding depth, though as yet no borings have been made which reach its rock floor. The comparative size of the valley of the Mississippi in its new channel across the lower rapids, and the par

[1] Tenth Census of United States, 1880, Vol. XVII, p. 60.

tially abandoned preglacial valley, is shown in cross-section in Fig. 1, furnished by the Iowa Geological Survey. The depth

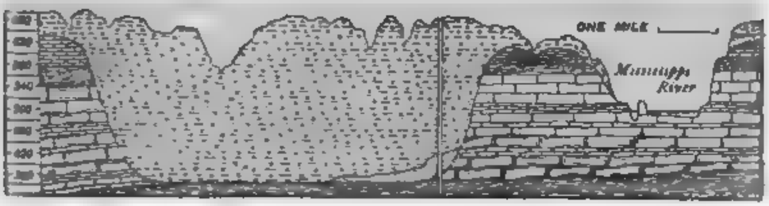


FIG. 1. Cross-section from Sonora, Ill., to Argyle, Ia., showing old and new channels of the Mississippi River (Iowa Geol. Survey).

of the new channel is but little more than half, and the width scarcely one-fifth, that of the preglacial channel. In size it is, therefore, scarcely one-tenth as large as the preglacial valley.

The small size of the Mississippi Valley at the lower rapids, compared with its size above and below, was noted by Worthen more than forty years ago, and interpreted to be an evidence that the greater valley is preglacial, while the portion of the valley across the rapids is postglacial. In the report of Hall, made in 1856, the following statement is found in the discussion of Lee county:[1] "The valley thus scooped out of the solid rocks extends from Montrose to the mouth of Skunk River, and is from six to eight miles in width. The eastern portion of this ancient basin, except the bluffs on the river above Ft. Madison, is now covered by the alluvial deposits before mentioned, while the western part is occupied by deposits of drift material from 100 to 185 feet in thickness. That this valley was formed by ancient currents previous to the drift period is proved by the fact that a considerable portion of it is now occupied by deposits of that age, and which must have been formed after those currents ceased to act." Again, in his first volume of the "Geology of Illinois," published in 1866, Worthen remarks (p. 9) that the present river has shown, by the work done in the upper and lower rapids, how inadequate its erosive power would be to

[1] Geol. of Iowa, Vol. I, 1858, p. 188.

excavate in postglacial time the entire valley, which it now but partially occupies.

A few years later General G. K. Warren discovered the abandoned section of the preglacial valley which crosses Lee county, Iowa, a few miles west of the lower rapids, and connects the portion occupied by the stream above the rapids with that below. In his report in 1878 he presented a discussion illustrated by a map setting forth the position of the old channel.[1] General Warren based his interpretations upon the absence of rock outcrops in the valleys which traverse the old course of the river, there being no borings that extended to the rock bottom. A few years later a boring at Mont Clare, Ia., was sunk in the old valley and brought confirmation to General Warren's interpretation.[2] The accompanying sketch map, Fig. 2, sets forth the position of the old valley and its relation to the one across the rapids.

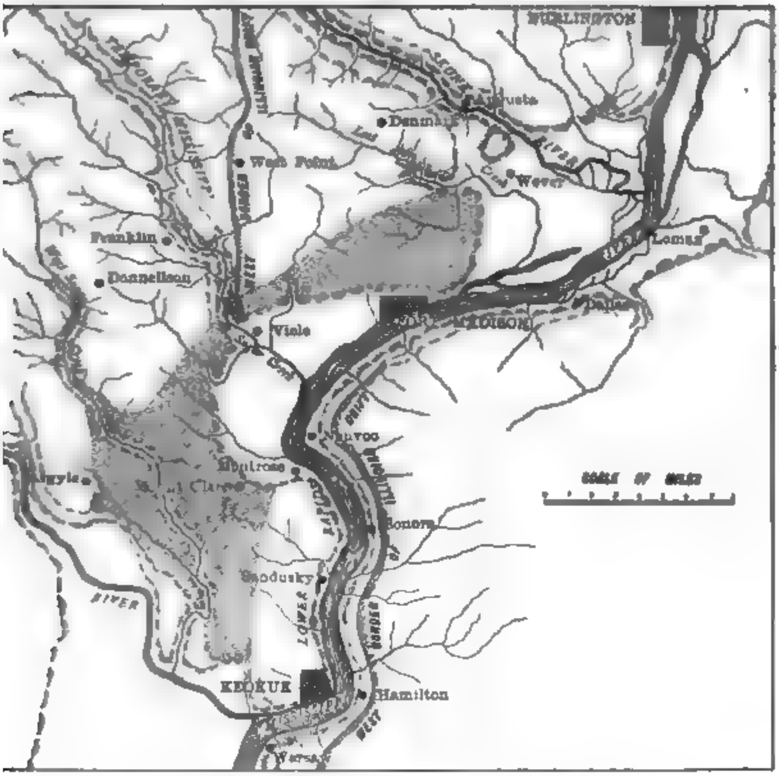
It should not be inferred that this broad preglacial valley was necessarily a line of discharge for the whole of the present drainage basin of the upper Mississippi. The available evidence concerning the preglacial drainage, though imperfect, is thought to indicate that a large part of the region above the upper rapids may have drained southeastward through the Green River Basin to the Illinois. Hershey has suggested a northward discharge for the headwater portion of the basin, a suggestion which awaits adequate investigation.[3] The preglacial valley which passes the lower rapids on the west is nearly coincident with the present Mississippi from the head of these rapids up to Muscatine, but its position farther north has not been ascertained, nor has the size of its drainage basin been even approximately determined. It is probable, however, that much of eastern Iowa was tributary to this preglacial line.

[1] Report of the U. S. Army Engineers for 1878–9, Vol. IV, Part 2, pp. 916, 917, Diagram E; also Diagram 1, Sheet 4.

[2] Buried River Channels in Southeastern Iowa, by C. H. GORDON, Iowa Geol. Survey, Report for 1893, pp. 239–255, Figs. 5, 6, and 7. Published in 1895 as Vol. III of the present survey.

[3] American Geologist, Vol. XX, 1897, pp. 246–268.

ate of the deflection across the lower rapids.—**In previous attention has been called, both by Mr. Fultz and myself,**



IG. 2. Sketch map of region discussed, showing course of old channels.

ote of Explanation.—The abandoned portion of the preglacial valley of the sippi is shaded. Hachures are used to indicate valley borders both above and the level of the high terraces, and along the temporary Mississippi channel, l at the Illinoian stage of glaciation. The extent of the high terrace south of s Moines Valley is not determined.

idence that the region around the lower rapids presents a licated glacial history.[1] It has been shown that one eld extended southward from Kewatin, in the Dominion of da, across Manitoba, Minnesota, and Iowa, into Missouri,

[1] F. M. FULTZ, Proc. Iowa Acad. Sci. for 1895, Vol. II, pp. 209–212; *ibid.*, 1896,

and that it spread eastward beyond the valley of the Mississipp from near the southern end of the Driftless Area of the upp Mississippi to the vicinity of Hannibal, Missouri. Two invasior may have been made by that ice-field with an intervening degl ciation interval of some length, as indicated by Bain.[1] Th later and probably the more extensive advance is referred to th Kansan stage of glaciation. It has also been shown that subse quent to the Kansan stage of glaciation an ice-field extende from Labrador and the heights south of Hudson Bay, southwest ward across Michigan, the Lake Michigan Basin, and Illinoi into southeastern Iowa.

The Kewatin ice-field not only covered the preglacial valle near the lower rapids, but also the district which the strear traverses in passing the rapids. It was thus liable to have dis placed the stream to a much greater extent than the deflectio past the rapids, as indicated below. The invasion from Labra dor, on the other hand, appears to have barely reached to th rapids and may not have interfered seriously with drainag across them, though it greatly disturbed the course of the Mis sissippi above the rapids. It did not reach the section of th preglacial valley west of the rapids. The deflection from th preglacial channel must, therefore, be due to the Kewatin ice field.

But since the Kewatin ice-field may have twice invaded th region it is necessary to inquire into the probable effect of each o its two invasions. If it be found that the earlier invasion extende beyond the line of the preglacial valley and deposited sufficien material to prevent the reëstablishment of the river along th preglacial line, some deflection at this early date must hav occurred. The deflection, however, need not necessarily hav thrown the stream into its present course across the rapids That course may have been taken as a result of the later invasio of the Kewatin ice-field, if not as a result of the still late

Vol. III, pp. 60–62; FRANK LEVERETT, Science, January 10, 1896; American Geol gist, February 1896; Bull. No. 2, Chi. Acad. Sci., May 1897; Proc. Iowa Acad. Sc 1897, Vol. V, pp. 71–74.

[1] Proc. Iowa Acad. Sci. for 1897, Vol. V, pp. 86–101.

ıcroachment of the Labrador ice-field. It is reasonable to ıppose that the deflection caused by the Kewatin ice-field ıight give the stream a course farther to the east than the lower apids, since the region across which the rapids have been opened ppears to have been entirely covered by the Kewatin ice-field ıt each of its invasions. It will be necessary, therefore, to letermine whether the Kewatin field did not establish the Mississippi in a course east of the rapids, and whether that course was not held by the Mississippi until the Labrador ice-field forced it westward into its present course across the lower rapids.

Turning now to the question of the influence of the supposed earlier invasion of the Kewatin ice-field, a few remarks seem necessary concerning the deposits made by that ice-field. The lowest conspicuous member of the drift series in eastern Iowa is a sheet of dark blue till, often nearly black, which is thickly set with fragments of wood and coal. This is overlain by a sheet of blue-gray till, which differs from the blue-black till in texture and rock constituents, as well as in color. It shows a decided tendency to break into rectangular blocks and often presents vertical fissures, extending to a depth of many feet, which are filled with sand and deeply oxidized clay. The blue-black till is very friable and seldom shows a tendency to break into rectangular blocks, while the few fissures which it contains traverse it in oblique rather than vertical lines. The blue-gray till carries much less vegetal material and coal fragments than the blue-black till. It differs also from the blue-black till in containing a larger percentage of greenstone rocks. These differences have naturally led to the suspicion that two quite distinct sheets of till are present, and this suspicion is confirmed by the occasional occurrence of a black soil at the surface of the blue-black till. Such exposures are rare compared with those of the Yarmouth soil, found between the Kansan and Illinoian till sheets,[1] but heir rare occurrence may not demonstrate that the interval of eglaciation is of minor importance. From conversations with alvin, Norton, and Bain, I am led to think that a large part of

[1] See JOUR. GEOL., Vol. VI, 1898, pp. 81–85.

the buried soils, reported by McGee from eastern Iowa,[1] occupy a horizon corresponding to the junction of the blue-gray and blue-black tills of southeastern Iowa. This being true the interval of deglaciation between the blue-gray and blue-black tills becomes of much importance.

The sheet of blue-black till has been found to occur at points farther east than the lower rapids. It occurs in the Mississippi valley in the vicinity of Ft. Madison, Iowa, and in Hancock and Adams counties, Illinois, east and southeast of the rapids. There is little doubt, therefore, that during the deposition of this till the Kewatin ice-field was *sufficiently extensive* to force the Mississippi out of the preglacial channel which passes west of the lower rapids.

It is not certain, however, that the *amount of filling* in that valley was sufficient to prevent the return of the stream to its preglacial course in the interval between the deposition of the blue-black till and the blue-gray till. The blue-black till in the vicinity of Ft. Madison is found to rise to a height of only sixty to seventy-five feet above the present stream, or nearly seventy-five feet less than would probably have been necessary to throw the stream from the preglacial channel into its present course across the rapids. This may possibly have been sufficient to throw the drainage of the portion above the lower rapids eastward into the Illinois, either by way of the Green River basin or by some line farther south, that is now completely concealed by the later sheets of drift. But it seems quite as probable that the stream returned to its preglacial course.

The blue-gray till seems to be fully as extensive a sheet as the underlying blue-black till. It extends eastward into Illinois beneath the Illinoian till sheet an undetermined distance. The tendency to break into rectangular blocks often serves to distinguish it from the overlying Illinoian till, as well as from the underlying blue-black till, though the Illinoian in places takes on this phase of fracture. Probably the most extensive of the

[1] Eleventh Annual Report, U. S. Geol. Surv., 1889–90, pp. 232, 233, 485–496, 541, 569.

exposures of the blue-gray Kansan till are found in the vicinity of Ft. Madison. They there constitute for several miles the upper 100 feet of the Mississippi bluff, except a thin coating of loess.

The filling produced by the blue-gray till was sufficient to prevent the return of the stream to its preglacial course, the altitude of the surface along the part of the preglacial channel west of the lower rapids being as great as in border districts. In this case, therefore, it is only necessary to decide whether the stream assumed its present course across the lower rapids at the time the Kewatin ice-field made its final withdrawal from that region, or whether it drained eastward to the Illinois until it was forced from that course by the advance of the Labrador ice-field, at the Illinoian stage of glaciation. Concerning this question it is thought that evidence of some value has been collected, as appears below.

Erosion preceding the Illinoian stage of glaciation.—The Mississippi valley for about fifty miles below the lower rapids was greatly filled by the drift from the Kewatin ice-field. Immediately below the rapids the filling on the borders of the valley reached a level about 150 feet above the present stream. It seems not improbable that there was a filling to nearly this height in the middle of the valley, for the abandoned section just above was filled in its middle part to as great a height as on its borders. Upon passing down the valley the height of filling gradually decreases to the limits of the Kewatin drift near Hannibal. From the filling of tributaries near Hannibal it is estimated that the Mississippi valley could not have been filled to a height greater than seventy-five feet above the present stream. Below Hannibal the filling was produced by stream action rather than by glacial deposition and appears to have reached but little, if any, above the sand terraces of the valley, by fifty feet above the river. Now if this filling suffered but little erosion before the Illinoian stage of glaciation, it can reasonably be inferred that the drainage of the upper Mississippi did not pass across the lower rapids and through this part of

the valley until forced westward by the advance of the Labrador ice-field. But if a great erosion took place in this part of the valley prior to the Illinoian stage of glaciation there would seem good grounds for supposing that the stream assumed its present course soon after the Kewatin ice-field made its final withdrawal.

Examining into this question it is found that after this drift was deposited by the Kewatin ice-field, an erosion so great took place that it was removed throughout the greater part of the width of the valley down to a level scarcely fifty feet above the present stream at the mouth of the Des Moines, and to an equally low level at Hannibal. The depth of cutting appears, therefore, to have been about 100 feet at the mouth of the Des Moines, and perhaps twenty-five feet at Hannibal. It seems safe to assume an average depth of fifty feet for the entire section and a width of five or six miles, making an erosion of nearly three cubic miles of drift in the fifty miles below the mouth of the Des Moines River. It is scarcely necessary to raise the question whether this erosion could have been accomplished by the Des Moines and other tributaries of the Mississippi below the rapids, for it is evidently out of proportion to the work which these small streams would be able to accomplish since the Kansan stage of glaciation. It seems certain that the Mississippi River is responsible for the principal part of the erosion. This makes necessary the opening of the new channel across the rapids, for the old channel west of the rapids was not utilized by the river after the Kansan stage of glaciation, and no other line of drainage could have been adopted by the river that would pass through the portion of the valley below the rapids.

Evidence is found within the new channel, of an erosion such as the interpretation just given demands. In the south part of Keokuk, between the foot of Main Street and the mouth of Soap Creek the rock bluff rises but fifty to sixty feet above low water, and is capped by a bed of bowlders about twenty feet in depth. Attention was called to this bed some thirty years ago by Mr.

S. J. Wallace, of Keokuk,[1] and the view expressed that it is "old river shingle." Mr. Wallace stated that Dr. George Kellogg, of Keokuk, regarded it as the indication of an old fall at this place, but that he did not so regard it. This bed has been discussed at some length by Dr. C. H. Gordon in the Geology of Iowa,[2] and three interpretations for its origin are presented. (1) That it was formed by river action alone, *i. e.*, as an alluvial bar; (2) that it is due to the cutting down of a till sheet, the coarse material being left as a residue; (3) that it is a bowldery moraine dropped at the edge of the ice sheet at the Illinoian stage of glaciation.

Of the three interpretations the second seems to Mr. Gordon, as well as to the present writer, the most applicable. Dr. Kellogg's suggestion of a fall as the cause seems at least to be poorly sustained. A similar bowlder bed occurs near Warsaw, Ill. It there forms the capping of an eroded till surface and bears clear evidence of removal of the fine material by a stream and the retention of the bowlders as a residue. A bowlder bed is also found along the face of the west bluff of the rapids near Sandusky, about six miles above Keokuk, at a level forty to sixty feet above the stream, that probably was derived from the erosion of a sheet of till. It seems referable to the period of erosion that produced the beds at Keokuk and Warsaw. The exposure, however, is not sufficiently extensive to show clearly its relation to the till sheet.

The amount of erosion effected is so great that the beginning of this new channel seems to date from near the close of the Kansan stage of glaciation. This becomes more evident as we study into the later stages of the history of the river. Even if the river had been forced into a channel farther east than the lower rapids, it seems scarcely probable that it remained long in that course. It apparently began its work of opening the course across the rapids long before the Labrador ice-field had reached the region.

[1] Proc. A. A. A. S., Vol. XVII, 1869, p. 344.

[2] Geology of Iowa, Vol. III, 1893, pp. 252–255.

Filling at the Illinoian stage of glaciation.— Following this great erosion there came a partial filling of the part of the valley immediately outside the limits of the Illinoian drift sheet. It is well displayed below the rapids, and some remnants are to be seen along the borders of the rapids. This filling appears to have occurred at the Illinoian stage of glaciation. Evidence of this relationship is to be found in the connection, or close association, of this filling with the opening of a temporary course for the Mississippi across southeastern Iowa, which occurred at the time the Mississippi valley above the rapids was covered by the Labrador ice-field.

The drainage line referred to leaves the present Mississippi at the mouth of the Maquoketa, passes southward along that valley (reversed) to "Goose Lake channel," and thence to the Wapsipinnicon Valley, connecting with it a few miles above its present mouth. It follows up the Wapsipinnicon a few miles to the mouth of Mud Creek, a southern tributary, which, together with a small tributary of Cedar River, also called Mud Creek, furnishes the line of continuation for the old valley to the Cedar River near the great bend at Moscow. The valley continues southwest to the Iowa River along the course now followed by the Cedar in its lower twenty-five miles. It then passes southward from Columbus Junction to Winfield, and thence westward to Skunk River at Coppock, opening in its westward course two lines, one of which is now utilized by Crooked Creek. From Coppock the old drainage line follows the course of Skunk River southward to Rome, and Cedar Creek (reversed) to Salem. It there turns southeastward, being known as "Grand Valley" in northern Lee county, and joins the Mississippi about six miles west of Fort Madison, nearly opposite the head of the rapids. Its continuation was evidently across the rapids into the broad valley below Keokuk.

The altitude of the bottom of this old valley, near the head of the rapids, is fully 100 feet above the present stream, but connects well with the surface of the valley filling in and below the rapids. It is nearly 100 feet lower than at the point where it

leaves the Iowa valley, 75 miles to the north. The portion above the point where the Iowa is crossed has been so modified since the Illinoian stage of glaciation, that very little is known concerning its condition at the close of that glacial stage, but the portion south from the Iowa valley has been only slightly modified.

Very little material was deposited on the bed of the temporary channel of the Mississippi in the 75 miles from the Iowa valley to the head of the rapids, but a great filling occurred in the broad valley below, and some filling along the rapids, espeally at their lower end. The valley which, at the foot of the rapids, had been cut down to a level scarcely 50 feet above the present stream, was built up to 80 or 90 feet above the river at that point. The depth of filling is found to decrease upon passing down the valley and becomes scarcely noticeable at Hannibal. It is, therefore, much like a delta, formed where a rapid stream emerges into a sluggish lake-like body of water. It consists mainly of fine material, sand or silt, with few pebbles greater than ¼ inch in diameter. A fine gravel, however, appears at an exposure called "Yellow Banks" near the mouth of the Des Moines River. The bowlder bed in Keokuk, described above, received at this time a capping of sand 15 or 20 feet in depth. Sand deposits are also found at a corresponding level in Hamilton, Illinois, near the foot of the rapids, capping a low part of the rock bluff. Another possible remnant of the sand filling is found at Sandusky, Iowa, six miles above Keokuk, immediately back of the bowlder-strewn slope, noted above. It there rises about 80 feet above the river or to within 25 feet of the level of the bottom of the channel of the temporary Mississippi, ten miles to the north. No remnants of the filling have been noted in this interval of 10 miles, and it is thought probable that the rate of fall was so great above Sandusky that but little lodgment of material occurred.

In the portion of the Mississippi valley covered by the Labrador ice-field, at the Illinoian stage of glaciation, there appears to be no such sand filling as is found below the rapids, thus con-

firming strongly the above interpretation, that the sand filling occurred during this stage of glaciation.

In explanation of the small amount of material deposited in the bed of the temporary Mississippi, Professor Chamberlin has suggested to me, that the ground in which this channel was excavated may have been frozen at the time of excavation, its situation being on the immediate borders of the ice-sheet. and that this frozen condition of the ground may have prevented the stream from eroding more material than it could readily transport.

The time involved in the valley filling is a question of much interest, but one on which an estimate is very difficult to make. The filling of any given section is not the measure of the full work of the stream, but simply an index of the excess of material above the limits of transportation by the stream. To properly estimate the work in a stage of filling, it is necessary to compute the amount of material carried through the channel, as well as that deposited in it. It is doubtful if present methods of study are sufficiently refined to enable one to make even an approximate calculation of the time involved. It may safely be affirmed, however, that the filling under discussion progressed slowly, and that the time involved was sufficiently long to affect materially the chronology of the lower rapids.

Erosion conditions during the Sangamon interglacial stage.— Between the Illinoian stage of glaciation and the deposition of loess which accompanied the Iowan stage of glaciation, there was a long interval of time, during which the surface of the Illinoian drift sheet was subjected to leaching and weathering, and the formation of a soil. The name Sangamon has been applied by the present writer to the soil and weathered zone formed at this time, and may properly be made to denote the time interval.[1] Although the degree of weathering and leaching makes it evident that the interval was protracted, the valley excavation appears to have been comparatively slight, so far as depth is

[1] Proc. Iowa Acad. Sci., Vol. V, for 1897, pp. 71–80. JOUR. GEOL., Vol. VI, 1898, pp. 171–181.

concerned. This is true, not only in the region about the lower rapids, but throughout the entire exposed portion of the Illinoian drift sheet.

The erosion on the lower rapids appears to have been scarcely sufficient to remove the sand filling which occurred during the Illinoian stage of glaciation. It could have amounted to scarcely 20 feet in depth and was mainly in loose material. The limits of the erosion are determined by the level down to which the loess extends. That deposit appears nowhere *in situ* at a lower level than 65 to 70 feet above the head of the rapids. Its lower limits in the portion of the valley above the rapids are also as great as 70 feet above the present stream.

A study of tributary valleys in this region has shown that the streams meandered widely and performed a large amount of work, notwithstanding the shallow depth of erosion. For example, Skunk River, in southeastern Iowa, at that time meandered over a width of about two miles (see Fig. 2), whereas it is now confined to an inner valley scarcely one half mile in average width. It should be noted, however, that the erosion of fifteen or twenty feet, over a width of two miles, by a stream with sluggish current, may involve more time than is required for the cutting of the inner valley, which has an average depth of nearly 100 feet and a width of about one-half mile. In this interval, as in the interval of filling which preceded it, the rapids suffered but little modification, yet the time involved was sufficiently long to affect materially the estimates of the duration of the stream in its present course.

The loess filling accompanying the Iowan stage of glaciation.—The period of low gradient and slack drainage, just discussed, was followed by even less favorable conditions for the opening of a channel. During the Iowan stage of glaciation, as long since pointed out by McGee,[1] and elaborated by Calvin and others,[2] the deposition of a sheet of silt occurred, not only along

[1] The Drainage System and Distribution of the Loess of Eastern Iowa, by W J McGee, Bull. Washington Phil. Soc'y, 1883, Vol. VI, pp. 93–97. Also, see discussion in Eleventh Ann. Rep. U. S. Geol. Surv., 1889–90, pp. 435–471.

[2] Geology of Jones County, by S. Calvin, Iowa Geol. Surv., 1895, Vol. V, pp.

the main valleys, but over much of the low country in the interior of the Mississippi basin. This silt is the problematical loess. Its mode of deposition is still a matter of dispute, the deposit being thought by some glacialists to be largely aqueous, while by others it is thought to be chiefly æolian.

In the region under discussion the valleys, as previously indicated, were opened only to shallow depths, hence only a slight accumulation of the silt was necessary to fill them, or to cause the streams to spread over the bordering plains. The depth of the silt in the vicinity of the lower rapids seldom reaches thirty feet, and probably averages not more than fifteen feet. Its bulk, therefore, does not, so far as the valleys are concerned, greatly exceed that of the filling which occurred below the rapids during the Illinoian stage of glaciation. If, however, the deposits on the bordering plains are taken into consideration, the amount of material deposited is very much greater, for the plains were covered to a depth of six to ten feet by this silt.

Whether the deposition took place by water or by wind, there seems to have been a suspension of erosion on the lower rapids, and the length of this suspension must certainly be sufficient to affect materially their duration. An estimate of the time involved seems at present impossible, there being fewer data for an estimate than in the filling which occurred at the Illinoian stage.

Erosion following the loess filling.—After the deposition of the loess, the valleys throughout much of the Mississippi basin experienced a marked deepening, which brought their bottoms to a lower level than before the loess filling. In the portion of the Mississippi valley, which lies within and near the rapids, the deepening seems to have proceeded continuously to a level nearly as low as the present stream, or fifty to seventy-five feet below the excavation which occurred in the interval following the

63–69. Geology of Johnson County, by S. CALVIN, Iowa Geol. Surv., 1896, Vol. VII, pp. 39–45, 86–89. Geology of Linn County, by W. H. NORTON, Iowa Geol. Surv., 1894, Vol. IV, pp. 168–184. Geology of Marshall County, by S. W. BEYER, Iowa Geol. Surv., 1896, Vol. VII, pp. 234–238. Geology of Plymouth County, by H. F. BAIN, Iowa Geol. Surv., 1897, Vol. VIII, pp. 335–351.

Kansan glaciation. This excavation in the section embraced within the rapids was mainly rock, for the loess and alluvium had built up the channel scarcely thirty feet above the rock floor of the post-Kansan erosion. But for some distance, both above and below these rapids, the excavation was largely in till. The channel across the rapids was opened to a width but little greater than the stream, or about one mile. Elsewhere the channel is three to six times the width of the stream.

This erosion seems to have continued until the early part of the Wisconsin glacial stage, when, as indicated below, another filling occurred. The extent and depth of the erosion which took place prior to the Wisconsin filling is well shown in the broad portion of the valley above the rapids. Numerous wells indicate that the till had been removed nearly to present river level over the greater part of the width of the valley before that filling set in.

The amount of erosion in the Mississippi valley seems to have been nearly as great in this interval as in the post-Kansan interval of erosion. It is doubtful, however, if the time involved was so great as in that interval, for the gradient appears to have been higher. To properly estimate the time involved, it is necessary, also, to know the volume of water discharged through the valley at each interval, a matter concerning which very little is yet known.

Filling at the Wisconsin stage of glaciation.—At the Wisconsin stage of glaciation the Mississippi and several of its tributaries, which flowed away from the ice-sheet, became so burdened by glacial detritus that they were unable to completely transport their load, much less to continue the erosion of their valleys. The Mississippi headed in the ice-sheet near St. Paul, Minnesota, while the Chippewa and Wisconsin rivers brought material from the Chippewa and Green Bay lobes of Wisconsin. Rock River, also, brought material from the Green Bay lobe, and through its tributaries, Kishwaukee and Green rivers, from the Lake Michigan lobe. Just above St. Louis the Illinois River contributed a large amount of material derived from the Lake Michigan lobe.

These streams discharged such large quantities of sand into the Mississippi that the valley was greatly filled as far down as the head of the broad valley of the lower Mississippi at Cairo. Throughout much of the interval between St. Paul and Cairo the valley was filled to a height of fifty to seventy-five feet above the present stream. In the vicinity of the rapids it reached nearly fifty feet above the level of the erosion in the preceding stage of deglaciation.

The filling probably began during the early part of the Wisconsin stage of glaciation, but the great bulk of it appears to have been contributed during the part of the Wisconsin represented by the Kettle morainic system. The transportation of sand down the valley no doubt continued for a long time after the ice-sheet had ceased to contribute material to the headwaters of the present Mississippi. The filling may, therefore, have occupied a longer time than that involved in the formation of all the moraines which cross the headwaters of the Mississippi.

The greater part of this filling consists of sand of medium coarseness. This, however, is interbedded with thin deposits of very fine gravel, and pebbles are also scattered through the sand. The pebbles seldom exceed one half inch in diameter and are usually one fourth inch or less. They have been noted by the writer as far down the valley as the vicinity of Quincy, Illinois. They are a conspicuous feature above Rock Island, Illinois. Upon following up the tributaries of the Mississippi toward the head of these valley trains, the material becomes markedly coarser, as is to be expected on the theory of their derivation from the ice-sheet.

It scarcely needs to be stated that so great a filling has greatly interrupted the removal of the rock barriers of the Mississippi at each of the rapids. A stream with the present volume of the Mississippi and its comparatively low gradient of about six inches per mile, can scarcely do more than remove the material brought in by its tributaries, to say nothing of removing the great amount of material deposited at the Wisconsin stage of glaciation. There appears, however, to have been a long period succeeding

this sand deposition in which the volume of the Mississippi was much greater than at present, and this matter will next receive our attention.

Erosion accomplished by the Lake Agassiz outlet.—Following this period of sand deposition the Mississippi valley afforded a line for the discharge of a large area now tributary to Hudson Bay, an area which was occupied by the glacial Lake Agassiz. The area of this glacial lake and of the country tributary to it is estimated by Upham to have been from 350,000 to 500,000 square miles.[1] This great drainage area has been reduced to about twelve thousand square miles[2] now tributary to the Mississippi through the Minnesota River. The present drainage area of the Mississippi above the lower rapids does not exceed 125,000 square miles, or about one-third the minimum estimate of Upham for the area of Lake Agassiz and its tributaries. Although this great reduction has been in the arid portion of the old drainage basin, it must greatly affect the volume of the river. The present run-off of that region can scarcely furnish a full index, since the ice-sheet was also a great contributor of water to the glacial lake. In addition to the change of drainage area involved in the glacial Lake Agassiz, it is necessary to take into consideration the influx of water from the glacial lake which occupied the western end of the Lake Superior basin, and also a small glacial lake at the head of Green Bay, Wisconsin.

It can scarcely be questioned that at the height of the discharge from Lake Agassiz the volume of water was fully four times that of the present Mississippi. This view is sustained, both by the amount of erosion which took place and by the low gradient reached by the stream. The sand which was deposited as a glacial out-wash while the ice-sheet occupied the head waters of the present Mississippi, was largely removed by the Lake Agassiz outlet, throughout the entire distance from St. Paul to Cairo. It is estimated that the average width of the channel

[1] "The Glacial Lake Agassiz," by WARREN UPHAM, Monograph XXV, U. S. Geol. Survey, 1895, pp. 50–64.

[2] Warren's Report, Bridging Mississippi River, Chief of Engineers U. S. Army, 1878–9, Vol. IV, p. 924.

formed by this outlet is three miles, or about four times the breadth of the present stream.

The depth of erosion seems to have been such as to give portions of the stream a lower level and a lower gradient than that of the present river. This is especially noticeable in the portion above the upper rapids, as indicated by General Warren.[1] Lake Pepin, an expansion of the Mississippi, situated just above the mouth of the Chippewa River has a depth of about sixty feet. It was General Warren's opinion that when the flow of water from the great northern basin ceased, there would no longer be the volume of water necessary to remove the deposits brought in by the Chippewa River. In consequence of this change the Mississippi has been lifted to a level about sixty feet above its former bed. Evidence of a similar filling, produced by the Mississippi at the mouth of the Minnesota, is cited by General Warren. He also noted evidence of the marked shoaling of the Mississippi at the mouth of the Wisconsin. He further expressed the opinion that the entire cutting now in progress on the Mississippi may be confined to short sections in the vicinity of the rapids.

It is of interest to note what a slight change is required to stop the cutting at these places. A filling of only twenty-five feet at the mouth of the Des Moines, or of Rock River, is necessary to cause the neighboring rapids to become protected from erosion. It is not probable, however, that either of these tributaries will for some time, begin the filling of the valley at the foot of the rapids, for the fall of the Mississippi, in passing each of the rapids, is greater than that of the lower course of the Rock, or the Des Moines. Furthermore the main stream has the advantage of much greater volume than these tributaries, in consequence of which the fall across the rapids must be reduced below that of the tributaries before filling can begin at their mouths.

Contours of the bluffs along the lower rapids.—The great length of time involved in the development of a channel across the rapids is shown by the contours of the bluffs. Except at a few

[1] Op. cit., pp. 911–916.

points where the river in rounding a curve has recently encroached upon its bluff there is not an abrupt face. A large part of the slope is so gradual that it has been brought under cultivation. When it is considered that the bluff is composed mainly of a firm limestone, the height of the rock portion ranging from 50 up to 150 feet, with an average height of nearly 100 feet, the prevalence of a moderate slope must indicate a long period of excavation.

But little is yet known concerning the manner in which the rock barrier has been cut away, whether by the recession of a fall, or by the present process of slow cutting across its whole breadth. The fact that the old valley below the rapids was filled with drift about to the height of the highest part of the rock barrier, lends support to the view that there has been a slow cutting down of the entire width of the barrier, rather than the recession of a fall. It seems scarcely probable that the till beneath the stream was scooped out to a much greater degree below the rock barrier, in the early stages of excavation, than at the present day.

Comparison with the upper rapids. — The work performed in cutting away the rock barrier at the lower rapids appears to be several times as great as at the upper rapids. In the latter, the rock excavation has not been sufficient to remove the prominent parts of the barrier. It scarcely amounts to an average cutting ten feet in depth, or one fortieth of a cubic mile. In the rapids under discussion, the barrier is estimated to have suffered a rock excavation to a depth of nearly one hundred feet, or about one fourth of a cubic mile. This difference in amount of work accomplished is readily accounted for by the earlier date at which the lower rapids began excavation. The excavation, as shown above, appears to have been begun soon after the Kansan stage of glaciation, while the excavation at the upper rapids appears to have begun after the Illinoian and to have been mainly accomplished since the Iowan stage of glaciation.

The lower rapids as a chronometer. — When this investigation was entered upon by the writer, hopes were entertained that the

channel across the lower rapids would furnish a valu nometer for determining the time since the Kansan sta ciation. But from what has been shown, it is eviden determination of the time is at present very difficu impracticable. It may be thought that this channel w a chronometer for the relative dates of the Kansan, Iowan, and Wisconsin glaciations. But on this questio more than a very rude approximation is likely to be As indicated above, the work involved in filling is ver to determine. These difficulties, however, are no gr those involved in the estimates of the changes of drai which the Mississippi has experienced. The object of ent paper is accomplished if the complexity of the hi been adequately presented. The chronological deter must be deferred to a time when more refined methods tigation are instituted than are now at command.

FRANK LE

NEWARK ROCKS OF NEW JERSEY AND NEW YORK[1]

wark rocks extend across the northern part of New
ning a belt which is about thirty-two miles wide

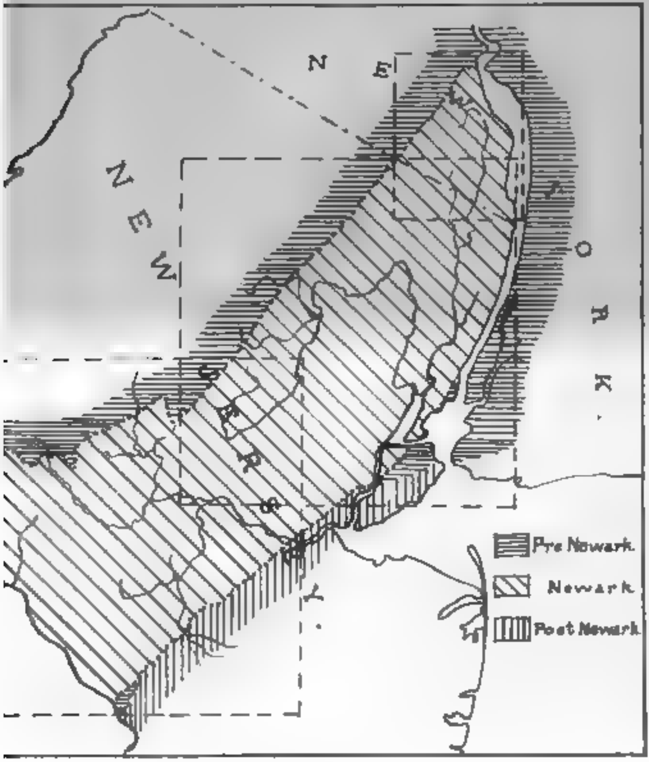


FIG. 1.—Newark area of New Jersey and New York.

Delaware River, and fifteen miles wide at the New line. In Rockland county, New York, the Newark a right triangle, the apex of which is near Stony

tailed accounts are given in the following papers: Annual Report of

Point and the hypotenuse along the Hudson River. The southeastern boundary from Trenton northeastward to Staten Island is for the most part formed by overlying beds, Cretaceous and younger. Near Trenton, however, the underlying Philadelphia gneiss outcrops for a few miles. The waters of the Kill von Kull, New York Bay and Hudson River form the boundary from Staten Island northward. The northwestern boundary is irregular and is formed entirely by older rocks — crystallines and Paleozoic shales and limestones. The general position of these rocks and their relations to the older and new formations are shown in Fig. 1.

THE ROCKS

The Newark series consists of sedimentary and igneous rocks. The former are chiefly shales, sandstones and conglomerates ; the latter, diabase, to which the more general term trap has usually been applied. Along the Delaware River (Fig. 2) the sedimentary rocks are divisible, on lithological grounds, into three groups, which have been called Stockton, Lockatong, and Brunswick.

Stockton group.— The basal beds of the series are found at Trenton where they rest unconformably upon the older crystalline rocks. They consist of (*a*) coarse, more or less disintegrated arkose conglomerates ; (*b*) yellow, micaceous, feldspathic sandstone ; (*c*) brown-red sandstones or freestones, and (*d*) soft red argillaceous shales. These are interbedded and many times repeated, a fact which indicates rapidly changing and recurrent conditions of sedimentation. Although there are many layers of red shale in this subdivision the characteristic beds are the arkose conglomerates and sandstones, the latter of which afford valuable building stones.

In addition to the cross-bedded structure which often pre-

the State Geologist of New Jersey for 1896, pp. 25 *et seq.;* Annual Report of the State Geologist of New Jersey for 1897, pp. 23 *et seq.:* JOUR. GEOL., Vol. V, pp. 541–562. A detailed account of the New York area will be published in the Annual Report of the State Geologist of New York, and a briefer summary in the Annual Report of the State Geologist of New Jersey for 1898.

vails in the sandstones, ripple-marks, mud-cracks and impressions of rain-drops occur. The rapid alternation from conglomerates to shales and *vice versa*, the changes in composition in individual beds, the cross-bedding, ripple-marks, etc., all indicate very

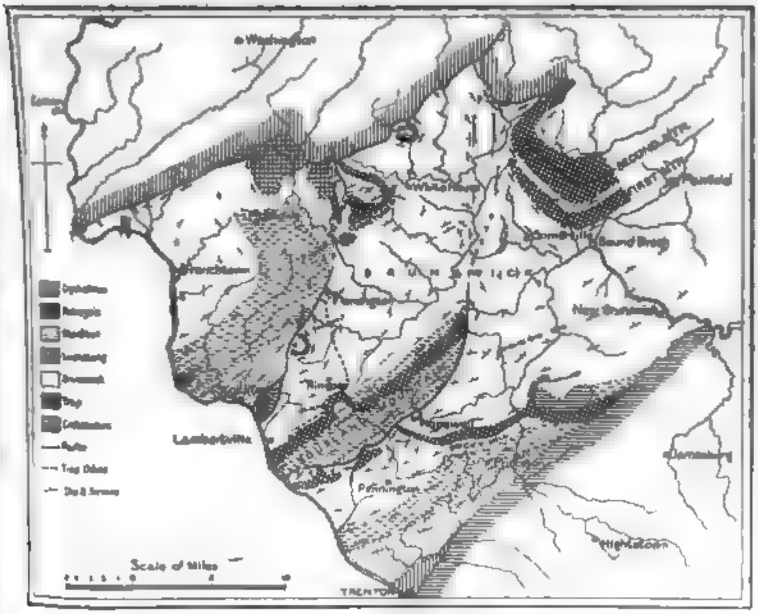


FIG. 2.—Subdivisions of the Newark rocks in Western New Jersey.

clearly that these beds were deposited in shallow water in close proximity to the shore. The bulk of the material of which they are composed was derived from the crystalline rocks on the south and southwest, but where they were found to rest upon Silurian shales, limestones and quartzites, as was the case along the northwestern border north of Flemington, material from these formations has determined their local character. The regions of the Stockton beds form gently rolling lowlands.

The Lockatong group.—These rocks overlie the Stockton beds conformably. They consist of (*a*) carbonaceous shales, which split readily along the bedding planes into thin laminæ, but have no true slaty cleavage; (*b*) hard, massive, black and bluish-

purple argillites; (*c*) dark gray and green flagstones; (*d*) dark red shales approaching a flagstone; (*e*) and occasional thin layers of highly calcareous shales. There are all gradations between these somewhat distinct types, so that the varieties of individual beds are almost countless. Both ripple-marks and mud-cracks occur at all horizons, showing that shallow water conditions prevailed throughout the time of their deposition. On the other hand, the absence of strong currents or violent shore action is indicated by the extreme fineness of the material.

The Lockatong beds are ridge makers, owing to their superior hardness and consequent resistance to the agents of degradation. In this particular they are surpassed only by the trap rocks. Sourland Mountain is composed largely of these rocks, although its backbone is formed by the outcropping edge of a trap sill. The high plateau in Hunterdon county, between Flemington and Frenchtown, which rises 300 to 500 feet above the adjoining region, is due also in large measure to the comparative indestructibility of these hard argillites and flags. They give rise to a rather heavy wet clay soil, often swampy unless artificially drained. The surface is quite thickly strewn with slabs of argillite and flagstone and on the steeper slopes rock outcrops are generally abundant.

The Brunswick beds.— In general this group consists of a monotonous succession of very soft argillaceous red shales which crumble readily to minute fragments, or split into thin flakes. Much of it is porous, the minute, irregular-shaped cavities being often partially filled with a calcareous powder. Calcite veins and crystals are common in some layers. Locally lenticular masses of green shale occur in the red. In size these range up to a foot or two in diameter, and vary in shape from nearly spherical to lenticular masses, narrowing down to thin sheets along cracks. They are undoubtedly due to chemical changes resulting in the leaching of the shale.

Although the majority of this series are soft red shales, there are some hard layers, chiefly near the base, and occasional beds of fine-grained sandstone and flagstones, some of which

afford valuable building material. Massive conglomerates along the northwestern border are in part the shoreward correlatives of the red shales.

Evidence that the shales were deposited in shallow water is abundant. Ripple-marks, mud-cracks and rain-drop impressions occur at many horizons. In some quarries imprints of leaves, of tree stems, or the stems themselves are frequently found. The numerous reptile tracks which have made the Newark beds famous occur chiefly in this subdivision. Typical exposures occur along the Raritan River, particularly near New Brunswick. The Brunswick beds are easily disintegrated and the fineness of the residuary material renders its transportation easy. Consequently the region underlain by these shales forms a lowland of faint relief, much of which has an elevation of only 100 to 200 feet above sea level. This plain is best developed in the drainage basin of the Raritan River, from New Brunswick northwestward to Flemington and White House. These rocks form also the western and lower part of the Hunterdon plateau in the vicinity of Frenchtown.

Owing to two great faults these three subdivisions each occur in three belts in the western part of New Jersey as shown by Fig. 2.

Lithological changes in these types. — Important lithological changes occur in all these beds as they are traced along their strike. As the northwestern border of the formation is approached, near Pittstown, the subdivisions lose their distinctive characteristics and merge along the strike into coarse sandstones and massive conglomerates. This change is most striking in the case of the Brunswick and the Lockatong groups, where red shales or black argillites change to sandstones and then into conglomerates, the pebbles of which are frequently six or eight inches in diameter. Under these conditions it is impossible to differentiate and limit these groups in this part of the field. Before considering these border conglomerates more fully, other modifications in the beds will be noted.

Important changes are found to occur as the beds are traced

along the strike northeastward into New York. The Stockton beds disappear beneath the later deposits a few miles east of Princeton. But owing to a slight change of strike they come to the surface again on both sides of the Palisades from Hoboken

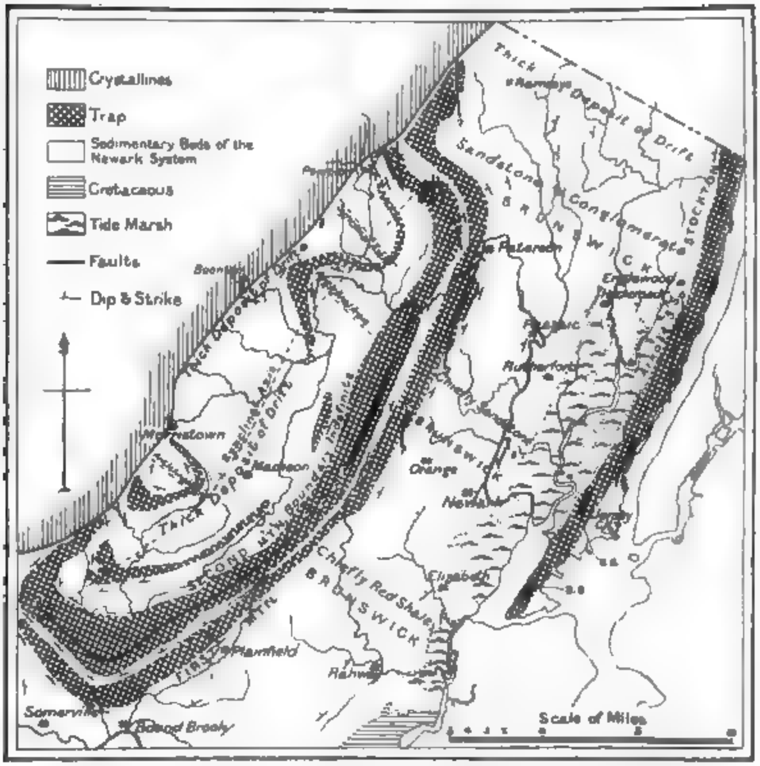


FIG. 3.—Newark rocks of Eastern New Jersey.

northward (Fig. 3). They are exposed in many places along the foot of the Palisades near the water's edge, and in a few localities where the glacial drift is thin, the typical arkose sandstone has been found on the west side of the Palisades. These rocks are correlated with those of the Trenton area for the following reasons. Lithologically, they are almost exactly identical; in both there are coarse arkose sandstones locally con-

glomeratic; in both, red shales and reddish-brown free-stones, and in both, these layers are several times repeated. Second, both occupy the same position stratigraphically. Near Trenton they are found resting upon the older crystalline rocks. In Jersey City wells bored near the water front strike gneiss and schist. At Stevens Point, Hoboken, the crystalline rocks outcrop, and, as is well known, they underlie the whole of Manhattan Island, just across the river. A little over half a mile back from the water front, in Jersey City and Hoboken, wells, which penetrate the glacial drift, reach sandstone and shale, some beds of the former being unmistakably coarse arkose. Third, minute crustaceans (*Estheria ovata*) have been found[1] in the shale beds at Weehawken and Shady Side along the Hudson River, and again in similar relations in the quarries near Trenton. Owing to the intrusion of the Palisade trap sheet some members of the group have been metamorphosed into hard, black and greenish flinty rocks, called hornfels by some German petrographers. Their occurrence, however, is limited to the neighborhood of the trap, and their presence in nowise affects the correlation of these beds with those near Trenton.

The Stockton beds certainly persist into New York, but the typical coarse arkose sandstone beds apparently thin out, and north of Nyack the group cannot be identified with any degree of certainty. The trend of the strata apparently carries the beds of this subdivision beneath the Hudson River.

Northeast of Princeton the outcrop of the typical Lockatong group grows narrower and the thickness less. Either the rate of deposition was slower to the northeast during the time represented by the Lockatong beds elsewhere, and therefore they are thinner here, or else, the rate of deposition being the same as elsewhere, the conditions favoring the deposition of black argillite and shale did not last so long to the northeast of Princeton as nearer the Delaware. A few miles northeast of Princeton the Lockatong beds also are covered by the Cretaceous deposits, but they have been traced by borings as far as

[1] NASON, Annual Report of the State Geologist of New Jersey, 1888, pp. 29–33.

the Raritan River. They do not, however, appear in the region west of the Palisades and north of Newark (Fig. 3). In the region in which they would be expected to occur the broad Newark and Hackensack meadows are found. The Lockatong beds are always ridge makers, rising above the level of the rocks on either side, and therefore it is impossible to suppose that they underlie these great tide-water meadows. There can be no doubt but that the argillites do not exist in the northern region. It is hardly probable that sedimentation ceased entirely in this northern area while the argillites were being deposited in the southwest, since there is no evidence of such oscillations of sea level or of unconformity. It seems more probable that the conditions favoring their formation did not prevail in the northern part of the basin; that here the red shales and sandstones were deposited contemporaneously with the argillites and flagstones to the southwest, and that, could we trace the latter from the point near Princeton, where they disappear beneath the Pensauken and Cretaceous deposits, we would find all the steps in their transition to the soft red shales.

The Brunswick beds likewise change in texture towards the northeast. They are predominantly soft argillaceous shales from the Delaware River as far as Elizabeth. In some layers an increase in coarseness is noticeable, which continues northeastward along the strike, until in the vicinity of Newark and Orange the beds are chiefly sandstones. Many of these beds resemble the brownstones of the Stockton series, so closely in fact that hand specimens can be distinguished with difficulty, if at all, from much of the sandstone at Trenton and Stockton. But their stratigraphical position in the Newark series seems to be far above that of the Stockton beds. The facts on which this conclusion is based are as follows. The trap sheet forming First Mountain is extrusive in origin. That is, it is an overflow sheet,[1] and, therefore, its base is conformable to the

[1] This might not be the case had the lava flowed over an eroded land surface, but evidence will be given below to prove that the lava flow was subaqueous, and therefore contemporaneous with the deposition of the adjoining shales. Its base therefore represents a constant horizon.

bedding of the sandstones, and represents a constant horizon. This being the case it gives us a reliable datum line. The position of the sandstones near Newark and vicinity in reference to the trap agrees with that of the Brunswick *shales* further south, and not with that of the Stockton sandstones. Second, they are too far removed from the base of the series, which follows the Hudson River, to be classed with the Stockton beds. Thirdly, when traced southward along the strike as closely as possible, considering the limited number of outcrops, they appear to grade into soft argillaceous shales.

Still further north layers of conglomerate appear interstratified with the sandstones and shales. In addition to well-marked beds of conglomerate, many layers of the sandstone contain pebbles scattered through them. The pebbles are chiefly of quartzite or sandstone, quartz, slate, limestone, feldspar, and rarely of flint. Not a single gneissic or granitic pebble was found, although careful search was made for them. The coarse sandstone and conglomerates, with some shale beds, continue through Bergen county, N. J., and Rockland county, N. Y. Since this phase of the Brunswick group is more resistant than the argillaceous shales in the Raritan basin, the topography is quite different. Where the Brunswick beds are soft red shales, the surface is a gently-rolling lowland, having an average elevation of from 100 to 200 feet above tide. With the appearance of the coarser and more resistant beds the general elevation becomes greater, and in place of the gently-rolling lowland, we find a series of ridges and valleys following very closely the trend of the beds. Toward the New York state line the higher of these sandstone ridges attain elevations of 450 to 625 feet above tide, the local relief being from 200 to 300 feet.

Owing to the disappearance of the Lockatong beds as a group possessing distinctive features, and the change in the Brunswick group due to the appearance of thick beds of brown sandstone and of coarse conglomerate, it is not practicable to differentiate on a map these groups as sharply as could be done

in the western part of the area. Their general distribution is indicated on the maps shown in Figs. 3 and 4.

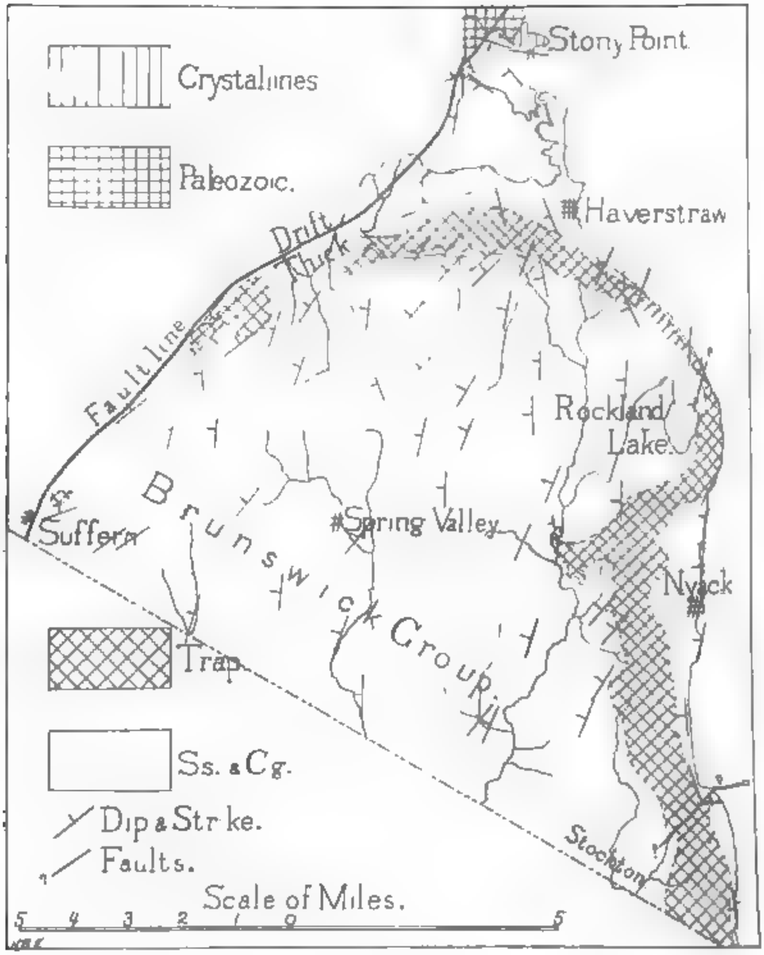


FIG. 4.—Maps of the Newark Series in Rockland County, New York.

Border conglomerates.—Beds of coarse conglomerate occu at a number of points along the northwestern border. Some o these are composed chiefly of quartzite, others of limestone and in one case of gneissic and granitic material. The quartzit

nglomerate contains a few pebbles of limestone, shale, and ieiss, but almost the entire mass of the rock is made up of iartzite or sandstone pebbles, which are well rounded and fre- ıently six or eight inches in diameter. They are best exposed the "pebble bluffs" along the Delaware River about five miles ove Frenchtown. The conglomerates are interstratified with ındstones and shales, forming lenticular beds, which thin out ithin a few rods, to be replaced by beds of a different texture. his alternation and rapid change betoken shore conditions. he quartzite conglomerate is also well developed (*a*) in "the larrens" northwest of Pittstown, (*b*) south of Clinton, (*c*) four iles north of Peapack, where there is an outlier called Mount 'aul, (*d*) south of Morristown, and (*e*) south of Pompton Lake.

The calcareous conglomerate is in appearance almost the xact counterpart of the famous "Potomac marble" quarried at 'oint of Rocks, Maryland.[1] The limestone pebbles are usually luish or gray, sometimes reddish, set in a red mud matrix, so hat the rock has a variegated appearance. The average diame- er of the larger constituents is six or eight inches, but bowlders ive feet in diameter have been seen, and at a quarry two and a ıalf miles northeast of Suffern, N. Y., bowlders twelve feet in liameter are reported to occur. The larger fragments are gen- rally rounded, but the majority of the smaller are sharp-cor- iered or at most subangular. Compared with the pebbles in the uartzite conglomerate, the limestone pebbles are but little worn, fact of some significance in connection with the origin and ource of the materials, since with equal transportation the softer nestones must have been most worn. In many localities this nglomerate is so pure a limestone that it is quarried and burnt r lime for local use.

Three small areas of this conglomerate occur northwest of tstown between hills of the quartzite conglomerate. A much ger area lies along the border northwest of White House. In w York state it occurs (*a*) two to three miles northeast of ffern, (*b*) near Ladentown, and (*c*) south of Stony Point.

[1] Geological Survey of Maryland, Vol. II, pp. 187–193.

Not uncommonly the most careful search failed to reveal a single gneissic or granitic pebble in the border conglomerates, even although the adjoining rocks were of this character. But east of Boonton a conglomerate composed chiefly of crystalline pebbles extends for two or three miles along the border.

Relations of these conglomerates to the older rocks.—The relations of these conglomerates to the older rocks along the border are significant. In some cases the calcareous conglomerates adjoin small areas of Paleozoic limestone, from which the materials may have been and probably were derived. In other cases, and *this is true of the largest areas*, the calcareous conglomerates abut against the gneissic rocks, and for much of the distance it is certain that no limestone occurs between the gneiss and conglomerate, at least not at the surface horizon. Crystalline pebbles, however, are comparatively rare in the conglomerate. Substantially the same conditions prevail in the case of the quartzite conglomerate. For the most part it adjoins the gneiss, but gneissic pebbles in it are rare. The known areas of quartzite along the border are small, and in general not near the massive conglomerate beds. Lithologically, moreover, they are unlike the bulk of the quartzite pebbles.

It is evident that along the greater part of this border the beds of the Newark series were not derived from the older rocks which now immediately adjoin them. Shore currents doubtless transported more or less material somewhat widely, and yet they do not afford us the complete explanation for these facts. The northwestern border is for the most part marked by faults. Here the dissimilarity of constitution is the most marked. Where the border is not faulted and the newer rocks rest undisturbed upon the eroded edges of the older beds, they are composed of fragments derived from them plus a small contribution by shore currents. Allowance can be made for the work of the currents, but the widespread dissimilarity of constitution is due chiefly to the faulting which has occurred. The waves of the sea in which the Newark beds were deposited did not on the northwest border in general beat against the rocks which now adjoin this area.

The relation of the conglomerates to the shales is also significant. They do not form a single horizon which may be used in interpreting the structure. Instead, they grade either into argillaceous shales, or black argillites, or arkose sandstones. Time and again the pebbly layers were seen to appear in the shales and to increase in thickness and numbers until they became massive conglomerates. This is true both of the calcareous and quartzite conglomerates, and probably also for the gneiss conglomerate, but owing to the glacial deposits its relation to the shales could not be determined.

The trap rocks.—The trap rocks of the Newark beds in New Jersey and New York have been described more or less in detail by several geologists,[1] and it has been demonstrated that overflow sheets, intrusive sills, plugs, and dikes occur. Owing to its superior hardness, the trap rock has better resisted erosion than the sedimentary beds, and consequently forms more or less well-marked elevations. In the case of narrow dikes, the elevation is slight and readily overlooked, but the greater masses form hills or ridges rising not infrequently 300, 400, or even 500 feet above their surroundings. The structural relations of the trap masses are among the most interesting questions connected with the Newark series, but only general conclusions can be given here.[2] The most important of the overflow sheets are the three concentric ridges forming the Watchung Mountains, Fig. 3. These sheets are to all appearances strictly conformable, both to the underlying and to the overlying shales. Nowhere is there any indication that the trap breaks across the sandstone or shale layers. Wherever the basal contact is exposed, and exposures several hundred feet in extent are known, the trap is seen to follow exactly the bedding plane of the shales.

Moreover, the extensive metamorphism of the associated sedimentary beds, a marked feature in the case of all the intru-

[1] Chiefly COOK, RUSSELL, DAVIS, DARTON, IDDINGS, KÜMMEL.

[2] Detailed descriptions are given by N. H. DARTON, U. S. Geological Survey, Bulletin No. 67, and by the author in the Annual Report of the State Geologist of New Jersey for 1897, pp. 58–100.

sive sheets, is entirely absent. Locally, the shale is slightly altered for a few inches beneath the trap, but even this is not always the case. When this is compared with the intense alteration which has affected the shales beneath the Palisades, an intrusive sill, for a distance of over 100 feet, the difference between the sheets is emphasized.

Upper contacts have not been observed in many cases, but the upper surface of these sheets is frequently vesicular, amygdaloidal, and scoriaceous. Locally, a thin layer of waterworn trap particles, intermixed with red mud occurs between the vesicular trap and the unaltered typical red shales, or the vesicles are filled with the red mud. The overlying shales conform to the slightly irregular, ropy surface of the trap. In frequent exposures the rolling-flow structure, named by the Hawaiian Islanders *Pa-hoe-hoe*, is visible. Nowhere have any tongues of lava been found extending from the main sheet into the neighboring shales.

In texture there is a marked difference between the overflow sheets and the intrusive sills. Not only is the trap vesicular and even scoriaceous at many points on the upper surface, but it is uniformly of much finer grain than that of the Palisades and similar ridges. Microscopic examination of fragments from the upper surface shows that volcanic glass occurs to some extent. The conclusions drawn from the texture are that these masses cooled much more rapidly than did the Palisade trap. Locally, vesicular and scoriaceous layers occur next to the under-shales, beneath dense, fine-grained trap. Generally in such localities the rolling-flow structure is clearly marked. The inference from these facts is that as the lava flowed onward the partially cooled vesicular slag-like and broken upper surface was rolled over to the under side of the flow, or in other cases, after a clinker-strewn crust had formed on the top and front of the sheet, the molten lava broke forth from within and flowed over and around the scoriaceous fragments, and on hardening bound them firmly together. Occasionally the red shale rises into the base of the trap, as if the great pressure and flowing motion of the molten

lava had forced upward the soft mud on the sea bottom, or as if the steam generated by the intense heat had made the wet mud to froth up between the trap clinkers. There can be no doubt as to the extrusive origin of these sheets.

The crescent-shaped ridges near Morristown, north of White House (near Germantown) and southwest of Flemington (near Sand Brook), are also overflow sheets.

Intrusive sills.—The Palisades of the Hudson, the Rocky Hill sheet north of Princeton, the Sourland Mountain sheet near Lambertville, and Cushetunk Mountain near White House, are the largest and most prominent of the intrusive sheets. Their position, size, and the shape of their outcrop are indicated on the accompanying maps. In addition to these, which are demonstrably sills or sheets, there are more irregularly shaped masses northwest of Pennington, near Stockton, and at Point Pleasant (west of Stockton), (Fig. 2), the precise relations of which to the inclosing beds are not clearly revealed. They are beyond all doubt intrusive masses, but it is questionable whether they are strictly sheets. In the absence of positive knowledge as to their relations with the sedimentary beds, I prefer to speak of them simply as intrusive masses.

The evidence of the intrusive origin of all these masses, sills and others, is as follows. Dikes radiate from the upper part of the sills and penetrate the overlying shales for distances up to seven miles, as measured on the surface. The sills are locally unconformable to the inclosing strata, although in general they extend for long distances parallel to their strike. The Sourland Mountain sill makes two sharp bends, by which it changes its horizon several hundred feet. The Rocky Hill sheet crosses the shales obliquely for a total of several thousand feet, and about twenty-five localities are known along the Hudson River where the Palisade sheet can be seen to cut across the shales and sandstones. In New Jersey the Palisade sheet follows closely the strike of the shales, although frequently changing its horizon a few feet. In New York, however, north of Nyack, the trend of the shales would carry it beneath the Hud-

son River, were it not that it ascends by irregular steps to higher horizons. West of Haverstraw it trends nearly at right angles to the strata, and is more like a dike than an intrusive sheet. A small area near Ladentown, which may be the western extension of the Palisades, presents some characteristics of an overflow sheet, indicating that possibly the trap here reached the surface. The adjacent sediments have often been greatly metamorphosed. So intense has been this alteration that at distances, often of 100 feet the rocks are as completely "baked" as those immediately adjoining the trap. Measured along the surface, traces of metamorphism are frequently found one foot from the nearest trap outcrop. The complete absence of scoriaceous rock, of amygdules, of the vesicular, or the rolling-flow structure, is negative evidence of their intrusive origin which must not be neglected. Moreover, masses of shale and sandstone have been imbedded in the trap near both the under and upper surfaces, and the trap itself shows evidence in its texture of having cooled more slowly (and therefore presumably at greater depths) than the overflow sheets.

Plugs.—Round Mountain, a circular mass of trap, south of Cushetunk Mountain, suggests by its shape, that it is an irruptive plug or stock, but in the absence of positive evidence as to its relations to the surrounding metamorphosed shales, no final statement is warranted.

Dikes.—The positions of the principal dikes are represented on the accompanying maps. A few others are known, but are too small to show on a map of this scale. Locally the adjoining shales are slightly metamorphosed.

The age of the trap rock.—The overflow sheets are contemporaneous with the beds between which they lie, *i. e.*, the upper third of the Brunswick shales.

The intrusive masses extend, for the most part, well up into the Brunswick shales, and are therefore younger than these. Moreover, so far as the evidence goes, they antedate the disturbances which closed the deposition of the Newark beds. There are good reasons for believing that many, perhaps all, of

the intrusive masses are younger than the extrusive sheets, although the evidence is not conclusive. From *a priori* considerations it may be suggested that the lava formed intrusive sheets after the formation became so thick that it could not readily rise to the surface; whereas, earlier in Newark time the lava was able to break through the thinner beds and overflow.

Metamorphosed shales.—The chief effect of the trap on the shales is the contact metamorphism which has been produced by the larger intrusive masses. The most marked macroscopical changes are (*a*) a greater or less induration, (*b*) change in color —red shales in general becoming purple and then a blue-black, streaked with gray or green near the trap, and (*c*) the development of secondary minerals, commonly epidote and tourmaline. The rock often has a banded or mottled appearance, due to the formation of lime-silicate hornfels. Of these three changes the third is the most significant. Mere induration or change of color does not necessarily signify "baking," but when all three occur together, and only in layers in close proximity to certain trap sheets, proved to be intrusive by their structural relations, the changes can be safely ascribed to the igneous rock. Many of the altered shales on weathering become a pale blue or ashy gray color, a tinge never taken by other layers.

Detailed microscopic study of the altered shales has been made by Messrs. Andreæ and Osann[1] from specimens collected at the base of the Palisades at Hoboken and Jersey City. Their results, which were published in Germany, are inaccessible to many readers in this country, and are therefore here briefly summarized. They group the metamorphosed rocks into four classes:

1. Normal slate hornfels, not distinguishable from hornfels formed by contact with intrusives which cooled at great depth.

2. Hornfels containing numerous tourmaline crystals.

[1] Tiefencontact an den intrusiven Diabasen von New Jersey. Separat-abdruck aus den Verhandlungen des Naturhist.-Med. Vereins. zu Heidelberg. *N. T. V.*, Bd. 1. Heft.

3. Metamorphosed arkose sandstone, distinguished by the formation of a fibrous green hornblende.

4. Lime-silicate hornfels (kalksilikat hornfelse).

The two first groups differ only in the presence or absence of tourmaline. They are very dense rocks, with a splinter-like cleavage and abound in biotite. Traces of the original stratification are preserved in the alternation of layers containing varying amounts of mica. The tourmaline always appears as a secondary mineral, in well-bounded black prisms up to three millimeters in length and one in width. They are without definite arrangement, the longitudinal axis being oblique to the stratification plane as frequently as it is parallel to it. Each of the tourmaline crystals is surrounded by a bright halo about half a millimeter in width, caused by the absence of biotite. This may be accounted for on the assumption that the iron and magnesia were consumed in the formation of the tourmaline. The biotite crystals have their tabular planes arranged parallel to the stratification planes.

Feldspar is the chief constituent of the tourmaline-bearing hornfels, and quartz is entirely wanting—a fact which indicates that the original sediment was very deficient in silica, but abounded in clayey materials.

From such rocks, presenting clearly a crystalline structure, a transition may be found to very dense masses in which, even when highly magnified, no constituent parts, save biotite, can be recognized.

The lime-silicate hornfels is bright gray to green-gray in color, dense and hard, and discloses, under the microscope, an irregular aggregate of very small grains, with strong double refraction, whose nature can be determined only from the larger grains. The minerals common to rocks of this variety occur; a colorless pyroxene, closely related to diopside; green hornblende; colorless tremolite in fibrous and radiating aggregates; garnet; vesuvian; epidote; while feldspar occurs commonly in diminished quantity. This rock frequently exhibits an alternation of bright and dark layers, in the former of which diopside usually prevails; in the latter green hornblende and biotite.

Solitary grains and crystals of titanite occur and frequent masses of calcite were observed. The lime-silicate hornfels effervesces with acid. Their occurrence here indicates a deep-seated origin for the Palisade sill.

The association of the slate hornfels and the lime-silicate hornfels is extremely interesting. The former makes up the main mass of the altered beds. The lime-silicate hornfels forms in most cases small layers in the slate hornfels, the thickness of the former often being no greater than that of a sheet of paper. These layers are parallel to each other and to the original stratification of the shales. Frequently they form small elliptical masses, joining each other like a string of pearls in the stratification plane. From this it is but a step to rocks in which the lime-silicate hornfels form only roundish eyes and knots in the hard, black slate, the "incipient segregation," which gives the rock a mottled appearance. In still other cases the lime-silicate hornfels traverses the darker hornfels in veins and bands at various angles to the stratification. Before metamorphism these were probably veins of calcite, which, together with the surrounding shales were altered on the intrusion of the trap.

In all these various relations the boundaries of these two rocks, of such different chemical composition, are sharply marked, both to the naked eye and microscopically. This is strong evidence that during the metamorphism these rocks were not molten, but that the changes occurred in solid, or at most, very slightly plastic beds. The authors conclude that the beds were originally argillaceous shales, locally strongly calcareous and traversed by veins of calcite and interbedded with layers of arkose sandstone. They find in the contact phenomena strong evidence that the trap was intrusive and cooled at great depths.

Metamorphosed shale, in every respect identical with these rocks, so far as macroscopical examination can determine, occurs along the Rocky Hill ridge, and is well shown along the canal near Rocky Hill village. Epidote and tourmaline-bearing shales occur on both sides of the Sourland Mountain trap, and are well exposed at Lambertville, where many of the features

noted by Andreæ and Osann can be seen. Fragments of altered shale can be found on the surface near the other intrusive trap masses, but there are no extensive exposures of the rock in place. Along the Palisade ridge the metamorphism is less pronounced near its northern end in New York, and not infrequently beds in close proximity to the trap here show no signs of alteration. Apparently, as the molten rock approached the surface, its effect upon the adjacent beds was diminished.

STRUCTURE

Folds.—The general structure is that of a faulted monocline the beds of which trend N. 20° to 50° E., and dip 10° to 15° to the northwestward. As a result of this, the layers to the northwest, save where faulting has occurred, are above, and therefore younger than the layers on the southeastern side. When examined more in detail, the structure is seen to depart locally from a monocline. Several broad, gentle flexures occur, in addition to a few sharply marked folds in the vicinity of the intrusive traps and greater fault lines. A good example of the former is seen in the shales of the Hunterdon plateau, where the beds are so inclined that their outcropping edges describe a great curve, parallel on the east, and southeast to the escarpment of the plateau. The structure is a shallow syncline, whose axis is inclined northwestward. Low folds occur in the valley of the Raritan, particularly in the region north of Somerville. From New Brunswick to Bound Brook the dip is quite uniformly to the northwestward, averaging ten degrees, but further to the west the monocline is interrupted by gentle flexures and swells which are difficult to trace because of the absence of individuality in the layers. The broad outcrop of the Brunswick shales in the Raritan valley is due in large part to these low folds.

More definite folds, all synclines, occur (*a*) near the Sand Brook trap sheet, southwest of Flemington, (*b*) the New Germantown trap sheet, and (*c*) the Watchung traps, whose great crescentic curves are due to the synclinal structure of the inclosing shales. Several examples of sharp folds occur near Glen-

more, southwest of Hopewell, and not far from the end of Rocky Hill. Other instances were noted near the faults.

In the area shown in Fig. 2, the Stockton and Lockatong beds are the more constant in dip and strike, so that the monoclinal structure is most marked in these belts. The Brunswick shales are characterized by shallow folds, some of them covering an area of several square miles. These, combined with a fortunate arrangement of faults, have greatly increased the area of red shale outcrop, and so permitted the formation of the broad, rolling lowland, so characteristic of the greater part of the Newark system.

Within the area shown in Fig. 3, the extrusive trap sheets are excellent guides in interpreting the structure, once their conformity to the shales has been completely demonstrated. The curved outline of the Watchung Mountains is due to a gentle synclinal fold, the westward side of which has been cut off by a fault along the highland border of the formation. The highest beds of the Newark series are those along the axis of this syncline. Between the Watchung Mountains and the Hudson River the monoclinal structure prevails. This is also true of the Newark beds of the New York area.

Faults.— About seventy-five faults are known to occur, and two of them, the Flemington and Hopewell faults, are of great magnitude and extent, causing a repetition of all three divisions of the Newark beds and involving dislocations equivalent to a vertical movement of one half the entire thickness of the series, perhaps 6000 or 7000 feet. Faults of such magnitude must extend downward beyond the limits of the Newark rocks, and involve the foundations on which they rest. Proofs of the faulting are found (*a*) in the repetition of the strata, (*b*) crushed and contorted strata, slicken-sided surfaces or overthrown dips at every exposure along or near the fault line, (*c*) diversity of structure on opposite sides of the fractures, (*d*) contrasts in the topography, and (*e*) the termination of ridges at the line of disturbance.

The northwestern border is formed in part by a series of

faults. Elsewhere the Newark beds rest upon the eroded edges of the older rocks. The faulted border is comparatively straight; the normal border is somewhat crooked. Along the former the shales dip in various directions in respect to the older rocks; along the latter they follow the trend of the contact and dip away from the older beds. In the one case Newark beds of very different horizons adjoin the border; in the latter they are basal beds. Along the faulted portion the Newark beds were not derived from the immediately adjoining older rocks; along the normal contact material from the adjacent old formations has entered largely into the newer beds.

The trap ridges, notably the Palisades and the first and second of the Watchung ridges, are cut by a number of faults which cross them obliquely. Second Mountain, moreover, is cut by a curving fault which follows the ridge for many miles, producing a double crest and revealing a strip of shale in the valley between. The throws of the faults rarely exceed 200 feet, save in the case of this longitudinal fracture where it is probably 700 feet or over. Owing to the monotonously uniform character of so many of the sedimentary beds, all estimates of the amount of throw are generally unreliable. Faulting is more frequent in the Brunswick and Stockton beds than in the Lockatong group, but the total number observed in all three subdivisions is hardly more than that found in the trap areas. There is good reason for believing that many faults which traverse the sedimentary beds have not been discovered, and perhaps never will be, with the present methods of geological research. With but few exceptions, all the known faults are reverse faults.

The thickness of the sedimentary beds.—In my earlier papers the following estimate of the maximum thickness of these beds was made.

Stockton, - - - -	4,700 feet.
Lockatong, - - - -	3,600 "
Brunswick, - - - -	12,000 "
	20,300 "

At that time it was felt that not all these estimates were

equally reliable. Six sections were made across the Lockatong beds with the following results: Across the belt on the Hunterdon plateau, 3540 feet, 3450 feet, 3500 feet; across the Sourland Mountain area, 3600 feet, 3650, 3660 feet.' The sweeping curve of this belt in the Hunterdon area, its uniform width, and the possibility of tracing certain subordinate but well-marked layers continuously along the strike preclude the idea that any great part of its apparent thickness is due to repetition by faulting. Furthermore, the fact that the beds on the Sourland plateau agree in thickness so closely with the same beds on the Hunterdon plateau is further reason for believing that the figures here given represent very closely the actual thickness. To suppose otherwise is to assume that these two separate areas are each traversed by faults, whose throw, by a remarkable coincidence, is almost exactly the same, but of which no traces have been discovered by areal work of the most detailed character.

The thickness of the Lockatong beds, near Ewingville and Princeton, seems to be only half of that in the other two regions, *i.e.*, 1700 to 1800 feet. The same relative thinness was observed in the Stockton beds, near Trenton, as compared with those further north. The explanation of this may lie in the fact that the beds of the former belt are nearer the old shore line than the others. Stratified deposits have the form of an unsymmetrical lens which thins out very rapidly shoreward and very gradually seaward. It is to be expected, therefore, that the thickness of this belt, which is nearest the old shore, would be somewhat less than that of the others. The weight of evidence indicates that in the deeper parts of the estuary the Lockatong beds were 3500 or 3600 feet thick.

The estimates for the Stockton and Brunswick beds are more uncertain. In favor of the estimates given above these facts may be urged. West of Ringoes the Brunswick shales form a syncline whose axis plunges northwest. Between 6000 and 7000 feet of shales are involved in this fold. It is improbable that a fault could follow the curving strike so as to repeat the

beds the same amount on both sides of the fold. Furthermo a narrow trap dike was traced uninterruptedly from the back Sourland Mountain, near Rocktown, to Copper Hill, a distar of five miles. The dike crosses the strike at an angle of for five degrees, and the thickness of the shales thus traversed between 6000 and 7000 feet. There are reasons for believi that the trap was intruded before the tilting and faulting. these reasons are valid the continuity of the dike is proof tl the shales traversed by it are not cut by faults along the stri Since such great thicknesses prevail in these beds, which are o a part of the whole, there is some reason for believing that t entire thickness of the Brunswick shales is near 12,000 feet.

On the other hand the disparity in the number of kno faults in the trap areas and in the sandstone and shale ar indicates that there are probably more faults in the sediment beds than have been discovered. The apparent thickness of t Palisades and the two Watchung ridges is from one half to o third greater than the actual thickness, the increase being due the faults. If the same proportions hold for the Stockton a Brunswick shales the figures given above will be somewl reduced. The revised estimate, therefore, is as follows:

Stockton, - - -	2,300 to	3,100 feet.
Lockatong, - - -	3,500 "	3,600 "
Brunswick, - - -	6,000 "	8,000 "
	11,800 "	14,700 "

There is so much uncertainty connected with all measu ments where there are so many unknown elements that the estimates may be far from correct. It certainly can be claim for them, however, that they rest upon a much larger basis fact than many previous figures.

Of the trap sheets.—The thicknesses of the various trap she are not included in the above estimates.

The Palisades at Jersey City Heights have at least a thic ness of 364 feet (well-boring), with a total thickness, includi the amount removed by erosion, of 700 to 800 feet, accordi

to estimates made from the angle of dip and the width of outcrop. At Fort Lee a well penetrated the trap for 875 feet before reaching the underlying metamorphosed shale and the total thickness here is about 950 feet.

In New York the thickness varies considerably, judging by the width of outcrop. A thickness of considerably over 700 feet is known to occur north of Nyack, whereas north of Rockland Lake it probably does not exceed 300 feet.

The thickness of First Mountain at Paterson is estimated to be 600 to 675 feet; at Orange Valley about 670 feet; at Scotch Plains about 680 feet, and at Chimney Rock about 580 feet.

With the exception of the thickness at Scotch Plains these figures agree closely with those obtained for First Mountain by Darton along the same sections. At Scotch Plains the outcrop is narrower than elsewhere, but the dip of the inclosing shales is steeper and his estimate of 450 feet is probably too low.

The thickness of Second Mountain is apparently somewhat greater than that of First Mountain, but owing to the faults which traverse it, estimates are liable to error. Darton's figures range from 600 to 850 feet. My own estimates, based on the width of outcrop and the dip, range from 840 feet to 990 feet. At Caldwell the well at the Mount St. Dominic Academy penetrated the trap for nearly 800 feet, but some addition must be made for what has been removed from the crest of the ridge by erosion.

At Millington the thickness of the Long Hill trap sheet is about 300 feet. At Pompton a well drilled at the Norton house is reported to have passed through but seventy feet of trap before reaching sandstone. Hook Mountain, east of White Hall, has an apparent thickness of 400 feet or more.

The New Vernon trap-sheet has a thickness of about 250 feet, measured at the gorge near Green Village.

The outcrop of the New Germantown sheet is comparatively narrow, but the dip is steep and the thickness is estimated to be at least 400 feet.

The same thing is true of the Sand Brook sheet, the thickness of which is apparently not less than 425 feet.

Too little is known of the relations of the Sourland Mountain, Pennington Mountain, Bald Pate, and Rocky Hill traps to the inclosing shales to venture estimates of their thickness.

Deposition.— Most geologists hold the view that the Newark beds are estuarine deposits. Some, however, prefer to consider them lacustrine, believing that the scarcity of fossil remains renders improbable the supposition that the sea had free access to the basin. The fauna and flora preserved for us are meager, and do not settle the question decisively, the forms being such as might have existed either in an estuary or a salt lake. On the other hand, the distribution of the material implies well-marked currents such as the tides would produce in an estuary. For myself I prefer to believe that at the beginning of Newark time a broad, shallow estuary extended across the northern part of what is now New Jersey and into New York state. Whether the estuary was wider than the present area of the beds is impossible to say. Subsequent erosion has diminished their areal extent, whereas faulting, particularly in the western part of New Jersey, has increased it. Which of these factors has been the more effective is uncertain. Probably along the Delaware River section the gain by faulting has exceeded the loss in width by erosion. In the north this may not be the case.

The estuary was bordered on the northwest and southeast by areas of granite, gneiss, and schist, probably pre-Cambrian in age, with narrow belts of Paleozoic quartzite, limestone, and shale. The latter rocks formed in part the floor of the estuary, the foundation on which the Newark deposits were made. This is shown by the "island" of limestone and quartzite brought to the surface in Pennsylvania by the Flemington fault. For long periods previous to the formation of the estuary and the deposition of the Newark shales, the older rocks on which they now rest had been a land area and were deeply eroded. The proof of this is found in the absence from this region of all the later members of the Paleozoic series.

The constitution of the arkose sandstones near Trenton and beneath the Palisades shows that the sediment was derived chiefly from older crystallines on the southeast, but scattered limestone and sandstones pebbles derived from the southwest show that the currents had a northward trend along the southeastern border. Along the northwestern border, where it is not marked by faults, the material was evidently derived from the adjacent rocks on the northwest.

The constitution of the Newark beds points to the conclusion that in pre-Newark times the old land surface was deeply covered with residuary material, the product of long-continued subaërial decomposition. On the crystalline areas it was chiefly quartz and feldspar or kaolin. The limestone was buried beneath a mantle of clay. In both cases the residuary products had been formed chiefly by chemical agencies. The sandstone and quartzite rocks were less affected by chemical changes and relatively more by mechanical agencies. Their surface was, therefore, covered by subangular fragments, due chiefly to the rending action of frost and expansion and contraction with changes of temperature. The almost complete absence of gneissic pebbles with the presence of quartz, feldspar and partially disintegrated ferro-magnesian minerals in the conglomerates, sandstone or shales proves that the crystalline rocks must have been deeply covered with a mantle of residuary material, so that streams, although they had velocity enough to carry pebbles two or three inches in diameter, did not corrade the bed rock, but worked in the residuary material.

The bulk of the Newark beds is so great as to indicate that these residuary products must have been very thick. Their accumulation was aided by gentle slopes, hindered by steep declivities. Previous to the formation of the Newark beds the neighboring land surface seems to have been one of low relief, with gentle slopes, across which transportation was reduced to a minimum. In other words, the land surface was approaching the peneplain stage.[1] Had the land been high and the slopes

[1] Practically the same conclusion has been reached by Professor Davis in regard

steep the accumulation of these residuary materials in a th mantle would seem to have been improbable. But the size of materials handled by the streams during the Newark time ir cates a velocity inconsistent with streams on a peneplain. would seem, therefore, that with the beginning of the New deposition the land regained something of its former ele tion. The rivers were able to carry from the crystalline ar pebbles of quartz or feldspar several inches in diameter and handle quartzite cobbles ranging up to a foot in size.

The massive border conglomerates are probably not cc posed entirely of stream-transported material. Limestone bo ders poorly rounded and measuring four feet in diameter h been seen, and some twelve feet in diameter are reported to oc in the calcareous conglomerates. All the coarser border c glomerates were probably accumulated by the waves which b against limestone and quartzite ledges. The scarcity of gnei: conglomerates indicates that the shores were not chiefly gneis as would be the case today were the Newark area to be s merged, but of limestone and quartzite. The faults along northwest border have, for the most part, cut out these roc and brought the Newark beds against the crystallines.

That the sandstones and shales were accumulated in shal water, is shown by the ripple marks, mud cracks, raind imprints, and footprints of reptiles and other vertebrates, wh occur at all horizons. At no time apparently was the water the estuary so deep that the outgoing tide did not expose br areas of sand or mud. It follows from this that there must h been a progressive subsidence of the estuary during the dep tion of these beds, since their thickness is to be measured thousands of feet. The subsidence went on *pari passu* with deposition of the sediments, since the shallow-water conditi prevailed continually. The progressive elevation of the adjc ing land areas, shown by the material carried by the rivers,

to the surface on which the Newark beds in Connecticut were deposited. His a ment, however, was along an entirely different line of reasoning, being based u the present topography.

complementary to this subsidence of the trough. If the subsidence were greater along one side of the trough than the other, the central axis must have shifted toward the side of greater depression, and the shore line on that side must have encroached upon the land. If this occurred to any marked degree during the later stages of sedimentation, the shore conglomerates of that time might rest upon the older rocks and so be basal conglomerates. At the same time they would be the correlatives of the topmost shales found further from shore. In this sense they would be the upper members of the series. This may have been the case locally along the northwestern border, and at the northern end of the estuary near Stony Point, but the evidence is far from conclusive on that point.

The lava flows.—Before the completion of the Newark sedimentation the quiet course of deposition was interrupted by great flows of lava. Whether the lava issued from a single vent or group of vents, or from a fissure is unknown. Certain it is, however, that the molten lava flowed over the soft mud in the bottom of the estuary. Locally the mud was forced up into cracks in the under side of the lava, or was thrown into low billows by the enormous pressure of the overflowing mass. The molten rock issuing forth into the water generated an enormous amount of steam, causing the mud to froth up and mingle with the scoriaceous lava. So, too, the more liquid lava flowed around and over the cooled and broken masses of clinkers, forming the ropy structure and the commingling of dense trap and breccia-like scoriæ sometimes seen in the Watchung trap sheets. Locally, perhaps somewhat generally, the lava flows were so thick as to rise above the sea level. In these cases the scoriaceous surface was readily eroded: the waterworn trap fragments were commingled with the red mud brought into the estuary by the rivers, and a layer of trap conglomerate or sandstone was formed. Such was the origin of the conglomerate in the back of the first Watchung sheet near Feltville. In other localities the vesicles on the upper surface of the lava were filled with the red mud as the lava flow was buried beneath the succeeding sediments. The three

Watchung trap sheets give us evidence of at least three peri
of eruption separated by long intervals of quiet, during which
deposition of the shales went on as regularly as before.
intrusive sheets were probably formed after the overflow sh
but this has not been conclusively demonstrated. Since both
intrusive masses (save perhaps some dikes) and the extru
sheets are cut by the faults, the volcanic phenomena prece
the faulting.

Professor Davis[1] has suggested that the disturbing f
which ended the deposition, was probably "a long enduring
slow acting horizontal compression, exerted in an east and v
or southeast and northwest direction; and that the explana
of the tilted and faulted structure is to be found in the writ
and rising of the inclined layers of underlying gneiss and sc
as they were subjected to this horizontal compression."
foundation on which the Newark sediments rest would thu
faulted and canted, and "the overlying beds, unable to sup
themselves unbroken on this uneven foundation, settle d
upon it as best they may." This explanation, offered to
the conditions of the Newark beds of Connecticut, is fully a
cable in its general features to the New York and New Je
area.

HENRY B. KÜMME

LEWIS INSTITUTE,
Chicago, January 1, 1899.

[1] DAVIS, U. S. Geological Survey. Seventh Annual Report, pp. 481–490.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. II

Essexite.—The term essexite was first introduced by Sears who applied it to a group of basic rocks composed essentially of augite, hornblende, biotite, and plagioclase, with subordinate orthoclase, nepheline. or sodalite, which he regarded as the earliest crystallized and most basic portion of the nepheline-syenite magma of Salem Neck.[1] Rosenbusch[2] enlarges the mineral list to include olivine and apatite, and erects the essexite into a group of igneous rocks of the same order as the granites or diorites. He says of them that they are related to the gabbro family as the monzonites are to the normal syenites. They may therefore be considered as essentially basic monzonitic rocks, in which both lime-soda and alkali-feldspars and feldspathoids are present, and which are usually, if not always, derived from an alkali, and especially a soda-rich, magma. In Essex county they are confined to the immediate vicinity of Salem Neck, where they occur in large masses, accompanying and cut by the nepheline-syenite. They are quite distinct from this, and, so far as I know, few transition forms into this rock have been seen. On the other hand, they grade into the diorites of the neighborhood, so that in this direction it is difficult to draw a hard and fast line. These rocks have been described by Sears[3] and by Rosenbusch.[4]

They are dark gray or almost black rocks, of a granitic structure, and usually fine-grained, though varying to some extent in this respect. Biotite and feldspar phenocrysts and small round spots of augite and hornblende are seen in most specimens, but are not prominent. Specimens from one locality

[1] SEARS, Bull. Essex Inst. Vol., XXIII, 1891.

[2] ROSENBUSCH, Elem. d. Gesteinslehre, 1898, p. 171.

[3] SEARS, loc. cit.

[4] ROSENBUSCH, Mikr. Phys., p. 247, 1896.

on Salem Neck show a marked subschistose or platy structure. Rosenbusch has described the essexites of Salem Neck in considerable detail, and in general my observations agree with his descriptions. He has, however, included among the essexites proper certain rocks with what he calls a hyperitic structure, which, it seems to me, are not essexites proper, inasmuch as they contain neither alkali-feldspar nor nepheline, but constitute a dioritic facies of it.

In thin section the structure of the essexites proper is granitic, though the plagioclase shows a tendency to tabular development. The feldspar is mostly a plagioclase, showing clear twinning lamellæ, whose extinctions vary, but which correspond to compositions ranging from Ab_1An_1 to Ab_1An_2. Rosenbusch speaks of it as "hoch idiomorph," but for my specimens this is rather strong. It is certainly much more so in the hyperitic facies, while in the more normal essexites (such as the one analyzed), it is only rarely so. An alkali-feldspar is not uncommon, generally anhedral, and often microperthitic. This, and a microcline which is occasionally met with, are apparently rich in soda. Nepheline is fairly abundant, generally interstitial, but occasionally in well shaped crystals. I could not identify with certainty any of the sodalite seen by Sears.

Rosenbusch speaks of two remarkable peculiarities of the feldspars. The first consists of the presence, in gray dusty crystals or portions of crystals, of minute biotites, or hornblendes, about which there is a dust-free zone; the other is the presence of specks and veins of a colorless substance of low refrangibility, and either isotropic or faintly birefringent, which he thinks might be either glass or nepheline. Of the first of these I could find no example in my sections, and of the second only a little here and there which did not allow me to answer the question which Rosenbusch raises as to its nature.

In the typical essexite of Sears the most common ferromagnesian mineral is a deep green or greenish-brown, highly pleochroic hornblende, basal sections of which often show prismatic planes. This occurs scattered through the mass in

highly irregular grains and prisms, and also accompanying a colorless diopside, of which it seems to be an alteration product. The hornblende in this case is not rarely bluish-green, and apparently contains some soda. The pyroxene, which is not abundant, is a colorless diopside, usually in large crystals, and nearly always altered more or less to the green hornblende. It sometimes shows such brilliant polarization colors as to suggest olivine, but the fine straight cleavage lines and the oblique extinction prove it to be a monoclinic pyroxene. Small flakes and stout tables of a greenish yellow biotite are quite common. Titanite, often showing lozenge-shaped sections as well as in irregular grains, is abundant. Small grains of titaniferous magnetite are rare, and in nearly every case form the nucleus of titanite areas, which are apparently their alteration product. Long slender prisms of apatite are very abundant.

Specimens of the schistose variety vary a good deal. In a specimen given me by Mr. Sears the feldspars are largely in small anhedra, and the structure is micrograniti c. Most of them are simple, perthites are not very common, twinning lamellæ rare. They have a brecciated structure and sometimes undulatory extinction, suggesting that the tendency to schistosity is due to pressure. Nepheline is present in considerable amount. Small irregular anhedra of a bright green aegirine-augite are scattered abundantly through the mass. A few large pale fawn-colored augites are seen, always more or less altered to a granular aegirite-augite. Small flakes of greenish-brown biotite and grains of titanite, often highly automorphic, are abundant, hornblende is almost wanting, and apatite scarce.

In other specimens the granitic groundmass is on a larger scale, the feldspars tabular and microperthite common, and interstitial nepheline abundant. An olive-green hornblende in beautifully automorphic crystals takes the place of the aegirite-augite, which is absent; large diopsides are rare, biotite almost wanting, titanite and apatite not abundant, and magnetite extremely scarce. No olivine was found by me in any of the varieties of the normal essexite.

The hyperitic variety is represented by two specimens from the southwestern part of Salem Neck, which only differ from Sears' type in being a little more coarsely crystalline, but much less so than the hyperitic diorites to be described later. The structure is somewhat ophitic, the feldspars being thick tabular, and the ferromagnesian minerals frequently xenomorphic towards them. At the same time these occupy bays and form inclusions in the feldspars, so that the crystallization must have been to a certain extent simultaneous. The chief peculiarity of the structure is the zonal growth of the biotite and hornblende about the pyroxene, olivine, and magnetite.

The feldspars are almost exclusively plagioclase, which is usually fresh, and with rather thick twinning lamellæ, whose extinction angles correspond to a basic labradorite, about $Ab_1 An_3$. Only a few grains of alkali-feldspar could be seen, and nothing which could be identified with nepheline. Olivine is present in some quantity, as rather large grains, usually automorphic though corroded. They are generally fresh, but sometimes partially serpentinized. A colorless or pale fawn-colored augite is present which shows high extinction angles. A reddish-brown barkevikitic hornblende is very abundant, showing the usual pleochroism; $\mathfrak{c}$=deep red-brown, $\mathfrak{b}$=deep red-brown, $\mathfrak{a}$=light brownish yellow, $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. It seldom forms independent individuals, but nearly always occurs as a border about the pyroxene and olivine. This border, which is usually of the nature of a reaction rim between the pyroxene or olivine and the feldspar, is highly irregular, often of great relative thickness, and in many cases almost entirely replaces the pyroxene. A brown biotite which is present in less amount also occasionally plays the same rôle. Magnetite and ilmenite grains are abundant, and about them is almost constantly found a hornblende rim when they are included in pyroxene, while, if they are included in feldspar, this is less common. Apatite is rare.

An analysis was made of a specimen from Salem Neck which was given me by Mr. Sears as representing his type. An analysis of a similar specimen, made by M. Dittrich for Professor Rosenbusch is given in II.

	I	II		I	II
SiO_2	46.99	47.94	BaO	none	....
TiO_2	2.92	0.20	Na_2O	6.35	5.63
Al_2O_3	17.94	17.44	K_2O	2.62	2.79
Fe_2O_3	2.56	6.84	H_2O	0.65	2.04
FeO	7.56	6.51	P_2O_5	0.94	1.04
MnO	trace	....			
MgO	3.22	2.07		99.60	99.92
CaO	7.85	7.47			

I. Essexite. Salem Neck. H. S. Washington anal.
II. Essexite. Salem Neck. M. Dittrich anal. (Rosenbusch. Elem. d. Gesteinslehre, 1898, p. 172. No. 1.)

The resemblance between the two analyses is close, the greatest differences being in ferric oxide, titanium oxide, and magnesia. It is possible that the low titanium oxide in Dittrich's analysis is due to the fact that it represents only the residue left after evaporation of the silica with hydrofluoric acid, while in mine, where the similar residue amounted to only 0.72 per cent., the titanium oxide was determined directly. The low silica and high lime and alkalies will be noticed, showing the basic monzonitic character of these rocks. Magnesia is rather lower than might be expected, a point which will be discussed later on.

Diorite.—This group is quite extensively represented in Essex county, the main occurrence being a long area with a general northeast-southwest trend in the western part, in Danvers, Topsfield, and Ipswich, a smaller area occurring about Salem and Marblehead and extending north into Beverly. From the large western area I have no specimens, all of mine coming from localities in the smaller areas about Salem and Marblehead. These rocks have been partially described by Sears[1] and are quite diversified in character.

Megascopically these are very dark, almost black, rocks, though a few are quite light, especially the main rock at Fort Sewall, Marblehead, which is a mottled light gray. This mass, by the way, is notable for the great number of "schlieren" and rounded masses of a dark, more basic diorite which it contains.

[1] SEARS, Bull. Essex. Inst., Vol. XXIII, 1891.

In structure they are always granitic, and in texture vary from rather fine to coarse-grain, the last looking like a typical diorite. The only minerals visible are white feldspars and black hornblende, biotite and augite.

Under the microscope it is seen that these rocks are essentially monzonitic in character, in Brögger's sense, orthoclase or an alkali-feldspar being almost invariably present along with the plagioclase, and that they vary from rather basic rocks rich in plagioclase and poor in orthoclase to more acid ones in which the orthoclase largely predominates over the plagioclase and where quartz also appears. The former closely approach the hyperitic varieties of the essexites, and, in fact, are only distinguished from these by their greater coarseness of grain and more dioritic appearance megascopically. The latter closely approach the akerites and perhaps should be described with them, but, on account of their intimate association with the dioritic rocks, and also because of their distinctly different megascopical character, they are placed here. Between these two extremes are found many transition types. The structure is always granitic or hypautomorphic, the dark minerals usually but not always, having crystallized before the feldspars, the plagioclase generally before the orthoclase, and the quartz, if present, being always interstitial. None of the specimens are quite fresh, the best in this respect being some from near Collin's Cove, Salem Neck, which are hyperitic in structure.

The plagioclase, which has a tendency to stout tabular forms, is highly, and in many cases beautifully, twinned, according to the albite and pericline laws. It varies considerably in composition from an oligoclase, Ab_2An_1, to a basic labradorite, Ab_1An_3, the former being more abundant in the more acid orthoclase-rich varieties and the latter in the more basic, especially in specimens from Salem Neck. It is usually xenomorphic toward the ferromagnesian minerals, but not always, and is also met with as inclusions in the latter, so that it seems that, although the latter began to crystallize first, during a later stage the crystallization was simultaneous. Inclusions of augite,

magnetite and apatite are not rare. A quite common feature is the presence of numerous minute black rods which are square or long in section and are probably magnetite. In the specimen from Peach's Neck which was analyzed a reaction between augite and plagioclase has produced small flakes of brown biotite along the edges of the latter and extending into its substance. The alkali-feldspar is less automorphic than the plagioclase, and is often microperthitic. The quartz, which is abundant only in the main rock of Fort Sewall, is always interstitial and clear, with minute glass or liquid inclusions.

The ferromagnesian minerals vary much not only in amount but in kind. A colorless or almost colorless monoclinic pyroxene is most abundant. This corresponds in general to diopside, but in certain specimens, Peach's Neck, and in black "schlieren" at Fort Sewall, it has the habit of diallage, a parting parallel to (100) and (010) being prominent. The diopside shows high extinction angles and carries few inclusions. The diallage, which has a tendency to light brownish hues, is frequently crowded with minute magnetite (?) rods, which in sections parallel to (010) are arranged parallel with the direction of extinction, at an angle of 34° with the cleavage cracks. They also carry the small brown or opaque plates which are so frequent in the hypersthene of gabbros. These are not pleochroic and are apparently isotropic. In the hyperitic facies from Salem Neck the pyroxene is a light violet augite. The pyroxenes alter easily to uralite, brown hornblende, and biotite.

Primary hornblende is not abundant and is to be referred to two varieties. In the main rock of Fort Sewall and in specimens from Peach's Neck it is pale green or olive-green, not very pleochroic, and automorphic as well as fragmentary. In the basic hyperitic rocks of Salem Neck it is brown, much more highly pleochroic, and is apparently a barkevikite. Biotite, when primary, is greenish yellow or brown, the latter especially in the hyperitic forms. Secondary hornblende and biotite are extremely common, formed usually at the expense of the pyroxenes, and often in the form of reaction rims. A few crystals of

olivine entirely altered to serpentine were seen, but they ar
rare to be of any importance. Magnetite is abundant in a
specimens, usually in large rounded grains. There seems
a tendency for biotite to be produced from it when includ
feldspar and hornblende when in augite, but this rule is not
stant. Apatite is abundant in fair-sized stout crystals, mo
in the basic than in the acid varieties.

It is evident that the rocks which are grouped unde
heading of diorite are highly varied and that they represent
sition forms from the essexites to the akerites. This is tr
least for the area under examination; of the larger Dai
Ipswich area I can say nothing. For the satisfactory stu
these rocks several analyses will be necessary, but at pr
only one is available. The rock chosen for analysis was a s
men from the south side of Peach's Neck, a coarse-grained
rock which shows under the microscope plagioclase, less c
clase, no quartz, diopside, diallage, magnetite, apatite, and
ondary hornblende and biotite. It is not quite fresh, bu
altered enough to affect the result seriously.

SiO_2	51.82	CaO	
TiO_2	2.15	Na_2O	
Al_2O_3	17.06	K_2O	
Fe_2O_3	1.97	H_2O (110°)	
FeO	8.60	H_2O (ignit.)	
MnO	none		
MgO	4.87		

This is evidently the analysis of a diorite, though a
one, the silica and alkalies being too high for a gabbro. I
be discussed later.

Quartz-augite-diorite.—The rocks which Sears calls by
name occupy a narrow area west of the rocks described i
preceding pages, which stretches through the county in a n
east-southwest direction from Andover to Newburyport an
New Hampshire line. Representing them I have only
specimens from Newburyport, given me by Mr. Sears, by v
they have been briefly described.[1] They are light gray, me

[1] SEARS, Bull. Essex Inst., Vol. XXVII, p. 7, 1895.

grained, granitic rocks, showing feldspars, augite, and a few quartz grains. The feldspars are apt to be epidotized. In thin section they show a granitic structure, and are composed of a rather basic plagioclase, about Ab_1An_2, nearly as much orthoclase, considerable quartz, stout prisms of pale green diopside which is commonly uralitized, some pale green biotite also altered, little or no magnetite, and rare small apatites. As all the specimens were badly decomposed I made no analysis of them, but they presumably approach in composition the nordmarkites.

Porphyritic diorite.—A peculiar rock which may be called a diorite is found, along with the orbicular syenite, in similar rounded masses enclosed in granite, near Bass Rock. It is dark-brown, with a rather fine-grained granitic groundmass of white feldspar tables and hornblendes, often surrounded by white feldspar zones, lying in a finer-grained matrix. Through this are scattered large phenocrysts of labradorite, up to 5^{cm} in length, of a peculiar clove-brown color and thick tabular habit. The cleavage of these is very good, and on basal cleavage surfaces fine twinning striations are visible.

Under the microscope the groundmass shows a granitic structure, composed largely of alkali-feldspar, with some plagioclase, small grains of colorless diopside, pale brownish-green hornblende, rare biotite flakes, considerable magnetite in grains and small stout rods, quite abundant apatite and no quartz. The large phenocrysts show well developed twinning lamellæ, which give extinctions corresponding to a labradorite of the composition Ab_2An_3. They are dusty with minute liquid inclusions holding movable bubbles, and also carry inclusions of diopside, hornblende, and magnetite. An analysis was made of a rather coarse-grained piece which was chiefly phenocryst, and this gave:

SiO_2	54.99	CaO	9.87
TiO_2	0.29	BaO	none
Al_2O_3	25.58	Na_2O	4.95
Fe_2O_3	0.43	K_2O	1.11
FeO	2.70	H_2O	0.38
MnO	trace		
MgO	0.72		101.02

This may be calculated roughly to represent:

Orthoclase,	6.5	Diopside,	2.1
Albite,	42.0	Hornblende,	3.2
Anorthite,	44.2	Magnetite,	2.1

Here the albite and anorthite molecules are in the ratio of 1 : 1, but since the microscope shows that the plagioclase has the composition of about Ab_2An_3, it is evident that the alkali-feldspar is rich in soda, and has approximately the composition Or_1Ab_2. The analysis, however, does not represent the composition of the rock as a whole, and for most purposes is of little or no use.

Gabbro.—Rocks which belong to this group are found in typical development only at Nahant, and are called norites by Sears, who has briefly noticed them.[1] According to Wadsworth[2] and Sears, gabbros also occur at various localities in Essex county, especially at Davis' Neck, Cape Ann, and Woodbury Point, Beverly. These, however, judging from the somewhat unsatisfactory specimens in my possession, are rather diorites in Brögger's sense, but will not be described further.

The gabbro of Nahant, as represented by the few specimens collected by myself, are dark, coarse-grained rocks composed of plagioclase, which even in the freshest specimens are dull or waxy and greenish through epidotization and black augite besides titaniferous magnetite grains. They show both megascopically and in thin section a typically granitic structure.

The abundant plagioclase, although rather decomposed shows twinning lamellæ whose extinctions correspond to those of a basic labradorite about Ab_1An_3. A little orthoclase also present. A pale gray augite is abundant, which is often automorphic and shows constantly high extinction angles. In my specimens I could find none of the hypersthene mentioned by Sears. Large titaniferous magnetite grains are common and are often surrounded by borders of leucoxene. With the exception of limonite, epidote, chlorite, and a few other decomposi-

[1] SEARS, Bull. Essex Inst., Vol. XXVI, 1894.

[2] WADSWORTH, Geol. Mag., 1895, p. 208.

roducts, these are the only minerals present. An analysis ade of the freshest specimen, which was slightly altered, near a cove on the north shore of Nahant, east of the e.

	43.73	Na_2O	2.42
	4.23	K_2O	1.45
	20.17	H_2O (110°—)	0.08
	4.32	H_2O (110°+)	1.02
	6.93	P_2O_5	0.15
	none		
	3.91		99.40
	10.99		

is low in silica, rich in lime, but rather poor in magnesia, in titanium oxide and alumina, and rather high in alkalies ch a rock, which is evidently a true gabbro.

ADDENDUM

Hyperitic diorite." — Since the description of this rock was put in an analysis has been made, which renders necessary some correc- and additions. The analysis is given here.

	I	II
SiO_2	45.32	49.25
TiO_2	1.94	1.41
Al_2O_3	18.99	16.97
Fe_2O_3	3.78	15.21
FeO	9.78	
MnO	....	trace
MgO	4.68	about 3.00
CaO	9.19	7.17
Na_2O	3.78	4.91
K_2O	2.12	2.01
P_2O_5	....	0.76
H_2O (110°)	0.09	about 0.30
H_2O (ignit.)	0.31	
	99.98	100.99

. Hornblende-gabbro, Salem Neck. H. S. Washington anal.

. Olivine-gabbro-diabase, Dignæs, Gran. A. Damm and L. Schmelck anal. . Brögger. Quart. Jour. Geol. Soc., Vol. L, p. 19, 1894.)

It will be seen that the rock is decidedly more basic than the other diorites of the region, so far as I am acquainted with them. The silica in fact is lower than that of the diabase and essexite, and closely approaches that of the gabbro from Nahant. This being the case, and the characters otherwise corresponding, the rock is not a diorite in the proper sense, as used by Brögger,[1] but should be called a hornblende-gabbro. It was thought at the time of the microscopical examination that the rock was basic, but it was not expected that it would turn out to be so low in silica as the analysis shows. At the same time the character of the hornblende, which is essentially a barkevikite, the rather high alkalies, and the association with essexite and foyaite show that these hornblende-gabbros ("hyperitic diorites") are decidedly distinct from the other diorites, and approach more closely the essexites and the more soda-rich rocks of the region. Attention has already been called to the fact that they grade into the essexites, and that Rosenbusch grouped them with these, but their decidedly lower alkali content and lack of orthoclase and nepheline sufficiently distinguish them.

It is to be remarked that these rocks resemble very closely under the microscope some of the gabbros of Norway, especially those from the district of Gran, and above all, some from the Viksfjeld. This is seen on microscopical comparison of sections of the rocks, some being mutually indistinguishable, and is also shown by the analyses, one of those of the Gran rocks being given in II for comparison.

H. S. WASHINGTON.

[1] W. C. BRÖGGER, Die Eruptivgesteine des Kristianiagebietes, Vol. I, p. 93, 1894, and Vol. II, p. 35, 1895.

THE SWEETLAND CREEK BEDS[1]

In Muscatine, Bloomington, Sweetland, and Montpelier townships, of Muscatine county, Iowa, some argillaceous beds are frequently found overlying the Cedar Valley limestone These contain a fauna quite different from that of the latter, and are unconformable with this as well as with the Coal Measures above. For reasons which will presently appear it is proposed to call them the Sweetland Creek beds.

Typical exposures.—Following the north bluffs of the Mississippi westward, the first occurrence of these beds is to be seen in the bank of a creek which comes down from the north, just east of the town of Montpelier. About twenty rods north of the bluffs the basal sandstone of the Coal Measures rests on some olive-gray shale, with green bands, rising about three feet from the bed of the stream in the right bank. This shale is altogether unlike the dark shale of the Coal Measures in appearance. The layers are more even and uniform. An unconformity between the two is also evident, and the lower formation soon disappears. In the river bluff the same creek is undermining a cliff of Coal Measure rock, which rests on the Cedar Valley limestone for the greater part of its length, but at the south end the base of the Coal Measures rises somewhat abruptly, first on an eroded slope of the limestone, and then over some decayed yellow clayey beds which intervene and run up ten or twelve feet above the limestone. The present condition of the bank does not afford an opportunity to closely study the nature of the clay beds, but in all probability they belong to the same strata as the shale above.

To the west of the town, a short distance up in Robinson Creek, and just northwest of Mr. G. W. Robinson's residence, some green clay is seen in the south bank of the creek, appar-

[1] Published by permission of the State Geologist of Iowa.

ently resting on the eroded surface of the Cedar Valley limestone. At the base of this clay there is a thin layer of more stony material, and this contains specimens of *Ptychtodus calceolus* and other small fish teeth. This is the basal layer of the Sweetland Creek beds. About one half mile farther up the same creek near the north line of section 23, in Montpelier township, just below a small fall in the creek, the following section is seen.

Number		Feet
13.	Coal Measures.	
12.	Dark bituminous shale with two or three bands of green shale; the dark next the green exhibiting a complex network of thread-like green extensions from ½ to 2^{mm} in thickness, lying approximately parallel with the bedding. Occasional lingulas found	1
11.	Dark bituminous shale with small spheroidal crystalline nodules of pyrites, occasional lingulas and *Spathiocaris emersoni* - -	2
10.	Concealed (next number a few rods farther down) - - -	2?
9.	Light greenish shale - - - - - - - - - - - -	1
8.	Dark olive-gray shale - - - - - - - - - - -	⅔
7.	Green shale - - - - - - - - - - - - -	⅔
6.	Greenish calcareous shale, almost stony, containing cylindrical or flattened fucoid markings slightly more greenish than the matrix	⅚
5.	Dark gray shale - - - - - - - - - - - - -	1
4.	Grayish-green pyritiferous rock with minute fragments of unrecognizable fossils - - - - - - - - - - - -	¼
3.	Dark gray shale - - - - - - - - - - - -	¼
2.	Greenish-gray somewhat stony shale exhibiting concretionary conchoidal fractures when weathered - - - - - -	¼
1.	Greenish-gray argillaceous and pyritiferous fine-grained dolomitic rock in layers a few inches in thickness, with fucoid impregnations or markings like those in number 6, ¼ inch in diameter -	1⅔

At the south end of this outcrop there is a small displacement in the ledges, which, dipping at a considerable angle south of it, soon disappear under the Coal Measures. The displacement is no doubt local and probably due to the falling in of some cavern in the underlying limestone.

Westward for the next three miles these beds do not appear, although the contact between the Coal Measures and the Cedar Valley limestone frequently comes into view. In the Pine Creek

basin they must have been removed by erosion previous to the deposition of the Coal Measures. Their next appearance is in Schmidt's run, about a mile east from the railroad station at Fairport. Just north of the wagon road under the bluffs they may be seen in the left bank of the run. There are several outcrops farther up, and the following section was made out, unconformably overlaid by the Coal Measures.

Number	Feet
4. Dark, almost black shale, with green seams from one to four inches thick, near which the darker shade exhibits a net work of filamentous extensions of green clay	7
3. Greenish light colored shale	3½
2. Greenish stony and hard shale	½
1. Greenish gray soft shale	1½

Just west of the railroad station at Fairport, where a wagon road follows a ravine up the bluff, this ravine exposes the following section.

Number	Feet
7. Coal Measures resting unconformably on the numbers below.	
6. Weathered shale of alternate light and dark layers	5
5. Dark gray shale	5
4. Grayish-green shale with two bands of darker shale in part perforated by coarse curving filaments or cylinders of green shale	3
3. Concealed	2 ?
2. Dark gray shale with curving cord-like cylinders of green shale about ⅙ inch in diameter	3
1. Greenish argillaceous dolomite in layers about 6 inches in thickness	1

In a small ravine which comes down from the west side of Wyoming Hill there is seen under and north of the wagon bridge about eight feet of gray and green shale with some stony layers. The Cedar Valley limestone comes out in the river bank just below and the Coal Measures overlie the exposure, rising about 100 feet above it.

Along Sweetland Creek the relation of these beds to the formations above and below them is better exhibited than at any other place in the county. About one-third of a mile north from the river bank they come out into view on both sides of

the creek, and they are also seen in a small tributary which runs into the creek from the east. Combining all the exposures at this point the following succession of separate layers is evident.

Number		Feet
11.	Dark gray bituminous shale with one or two thin green bands about four feet below the highest exposure. Occasionally small flat concretions of pyrites are seen. Next the green layer the shale is dark filled with a maze of fine green filamentous lines. Drift overlies	8
10.	Dark shale containing lingulas, ***Spathiocaris emersoni, Rhynchodus,*** and a fossil resembling *Solenocaris strigata.* This number is continuous with No. 11	1½
9.	Greenish clay with flat concretions of iron pyrites frequently having white stony lamellar extensions from the margin	3
8.	Dark shale	⅔
7.	Greenish stony shale with a conchoidal concretionary fracture,	⅓
6.	Hard light grayish-green shale with white flattened cylindrical fucoid concretions of a concentric structure in horizontal positions	¼-½
5.	Greenish argillaceous or arenaceous fine-grained dolomite in ledges from 4 to 10 inches in thickness, with occasional lingulas and a fragment of a cast of a gasteropod near the base, frequently exhibiting small cylindrical concretionary impregnations of a deeper green, and occasionally impressions of plant-like fibrous structure covered with a thin layer of bituminous material	3
4.	Greenish shale	1½
3.	A stony seam filled with finely granular pyrites and occasionally showing larger lumps of the same mineral in one instance associated with plant-like fibrous impressions, frequently containing rounded worn fragments of fish teeth	$\frac{1}{12}$-¼
2.	Green hard shale	⅔
1.	Greenish stony layer with frequent, mostly rounded, fragments of *Ptychtodus calceolus*	⅓

Under the lowermost layer containing fish teeth the uneven surface of the upper ledges of the Cedar Valley limestone is seen, and at least eight feet of this rock is exposed. In some of the shallow depressions in its upper surface a seam of black bituminous material is found. At one point this forms a layer two inches in thickness. Near the south end of the exposure farthest down the creek the upper beds come down over the

uppermost ledge of the limestone, which runs out as if worn away. The surface of the limestone has been partly uncovered by the creek. It is brown in color, uneven from erosion and frequently studded with nodules of iron pyrites or covered by a continuous incrustation of the same mineral. In the west bank of the creek the basal sandstone of the Coal Measures overlies the eroded edges of numbers 6, 7, and 8 in the above section, which rise under it in a hillock. In the gully to the east the section is continued higher up and the Coal Measures do not appear. Some distance farther up Sweetland Creek they are again seen unconformably overlying the dark gray shale in the east bank, with erosion contours extending down three feet into the lower formation. At this place the basal conglomerate contains rounded lumps of the dark shale, three or four inches in diameter. Still farther up the creek the darker shale corresponding to number 11 in the above section appears at several places in the bed of the stream, rising in one instance about five feet in the bank. The last seen is about one hundred paces south from the wagon bridge near the north line of section 27. In each of these places the characteristic green layers with their accompanying network of green threads in the confining dark shale may be seen.

About three fourths of a mile west of Sweetland Creek, near the east line of section 28, in Sweetland township, a smaller stream exposes the following section.

Number		Feet
5.	Coal Measures.	
4.	Alternate layers of dark and greenish shale - - - - - -	4
3.	Fine grained, light yellowish-gray, impure dolomite in thin ledges	2½
2.	Greenish shaly rock with a thin, harder layer below - - - -	2¼
1.	Upper ledges of the Cedar Valley limestone, ferruginous and worn superficially - - - - - - - - - -	1–2

In Camhel Run, which comes down to the river through the northwest corner of section 21, in the same township, a similar succession of layers is seen at the point where the stream passes the line of the river bluffs. The following section appears very clearly.

Number		Feet
11.	The base of the Coal Measures.	
10.	Dark gray shale with lingulas near the base	3
9.	Greenish shale	3½
8.	A layer of harder, almost stony shale	½
7.	Greenish-gray shale weathering with a conchoidal fracture into small spheroidal nodules and chips	1±
6.	Grayish, fine grained, impure dolomite	1½
5.	Greenish shale	1±
4.	A thin and stony, in places highly pyritiferous seam, associated with small selenite crystals when decayed, in places almost filled with rounded specimens of *Ptychtodus calceolus*	1/10-1/5
3.	Greenish shale	½-1
2.	Greenish fine-grained rock with fish teeth	1/6-1/4
1.	Upper ledges of the Cedar Valley limestone with a slightly eroded surface, frequently covered with pyrites.	

Number 10 in the above is seen in two or three places farther up in the creek, but it soon disappears under the base of the Coal Measures.

Along Geneva Creek, in the northwest quarter of section 29, in the same township, the basal layers of the preceding sections are seen in the bed of the stream opposite the Geneva schoolhouse, and below the wagon bridge. The main stony ledge forms the bed of the creek for a distance of ten or twenty rods a quarter of a mile farther up. About half a mile north of the schoolhouse the shale above this ledge rises some six feet in the west bank, and is overlaid by the basal conglomerate of the Coal Measures, from which a small spring issues. Combining these exposures the succession of the layers seen may be given as in the following section.

Number		Feet
13.	Basal conglomerate and sandstone of the Coal Measures.	
12.	Dark gray and ferruginous, evidently somewhat disintegrated dark shale	
11.	Light greenish-gray shale	
10.	Dark lavender colored shale	1½
9.	Green shaly rock	½
8.	Concealed	
7.	Green rock in even thin layers with regular vertical rather equidistant joints	1½

Number	Feet
6. Concealed	?
5. Greenish shale (opposite the schoolhouse)	1
4. Pyritiferous green stony layer with cylindrical straightish fucoid impregnations	¼
3. Green shale	1
2. A conglomerate of fish teeth, containing *Ptychtodus calceolus* and *Synthetodus* frequently in a worn condition and imbedded in a greenish argillaceous fine-grained dolomite	¼
1. Beds of the Cedar Valley limestone containing large fragments of Stromatopora, with the upper surface unevenly eroded.	

From this point westward no more is seen of the beds under consideration until we come to East Hill, in Muscatine. Under the south bluff of this hill the railroad bed has been excavated in the upper dark shale seen in the foregoing sections. These rise here about thirty feet above the bed of the road, and they have been so disposed to slip in the bank, that piles and a stone-wall have for many years been needed to keep the embankment from coming down on the track. These were removed late last fall and the face of the embankment was cut away several feet. This work left the shale well exposed. The section above and below the railroad bed is as follows.

Number	Feet
2. Dark or gray bituminous shale, with three parallel bands of green shale a few inches in thickness and about three or four feet apart, weathering into fine chips of a yellowish light gray color, containing small flat concretions of pyrites, joints in some of the freshly exposed shale filled with numerous small crystals of lenite disposed in branching patterns, the basal part containing sea lingula and exhibiting the peculiar network of green thread-like extensions observed in previous sections near the transitions to green shale	36
1. Green shale	2

The top of number 2 is unconformably overlaid by the Coal Measures, and has evidently been weathered previous to their deposition. Below number 1 the section is concealed in the river bank. The base of this layer is about ten feet above low water. There is little doubt that it is the equivalent of number

9 in the Sweetland Creek section, and the lower layers of the: beds may possibly all have been exposed above water at th point before the railroad embankment was made. As the lower layers aggregate about seven feet in thickness at oth places, it will be noticed that the extreme thickness of the who formation at this place is about forty-five feet. This is tl greatest thickness that has been seen anywhere in the county.

Just above the wagon bridge which crosses Mad Creek ne the center of the northwest quarter of section 24 in Bloomingt township, some ledges equivalent to numbers 6, 7, 8 and 9, in t Sweetland Creek section appear in the bank of a tributary frc the east. Again in the creek running east through the noı half of the northwest quarter of section 26 in the same townsh some thin ledges of rock and some green shale corresponding numbers 3, 4, and 5 in Sweetland Creek come into view frc under some Coal Measure beds.

Geographical distribution.—So far as known, the above plac include all the exposures of the Sweetland Creek beds in t county. There is good reason to assume that they under the Coal Measures in most of Muscatine, Bloomington, a Sweetland townships, and that scattered outliers occupy t same position in the east half of Montpelier township. In probability their outcrop in the river bluff is continuous fr Wyoming Hill to Muscatine, though mostly concealed by t talus under the bluffs.

General section.—The separate layers and ledges of the form tion have a remarkably uniform development, varying b slightly in different places. The basal layer, though only abo three inches in thickness, can always be recognized in its plac and invariably contains the characteristic fish teeth. From s inches to a foot above this layer there is a pyritiferous stoı seam from one-half to two inches in thickness, and this is readi identified in all the creeks in Sweetland township where the low part of the section appears. The peculiar maze of green threa which extend into the dark shale where this comes into cont with green layers have been observed in almost every case whe

they are due in the section, all the way from Muscatine to Montpelier. It is therefore no very difficult task to combine the local outcrops into a general section.

GENERAL SECTION OF THE SWEETLAND CREEK BEDS

Number		Feet
7.	Dark bituminous shale, occasionally containing small flat concretions of iron pyrites, with three thin bands of greenish shales respectively about 5, 9, and 12 feet from the base	33
6.	Dark shale, with thin seams of blue shale, the dark containing two species of lingula, *Spathiocaris emersoni*, *Rhynchodus*, and a fossil resembling *Solenocaris strigata*	3
5.	Greenish shale, with occasional stony layers, containing flat concretions of pyrites frequently bordered by lamellar marginal extensions of a white dolomitic material	3½
4.	Alternating layers of greenish stone and green and dark shale, the latter in part containing a network of thread-like extensions of the former. The green shale has elongated flattened concretions resembling fucoid growths and lying parallel with the bedding. The stony layers are frequently charged with small grains of pyrites and contain minute fragments of fossils	2
3.	Greenish fine-grained argillaceous magnesian limestone impregnated with iron pyrites and calcium phosphate, in ledges from 4 to 10 inches in thickness, with cylindrical fucoid impregnations slightly more greenish than the matrix and from 3 to 6 millimeters in diameter, containing two species of lingula, a fragmentary cast of a helicoid gasteropod, and imprints of some fibrous structure like that of some plant stem	3½
2.	Hard greenish-gray shale, with a stony pyritiferous layer that contains fish teeth and impressions of vegetable tissue about 10 inches from base	3
1.	Argillaceous dolomitic stony layer containing *Ptychtodus calceolus* and other forms resembling *Synthetodus*	¼

Lithological peculiarities.—The greenish ledges turn grayish-yellow on weathering. The main stony ledge, number 3, often protrudes as a shelf over the clay below it, which is more easily removed by erosion. In two instances an efflorescence of epsomite was noticed forming on the face of the clay thus protected from rain by the overhanging rock. The material found in the shells of the lingulas of this ledge was unaltered, but

in one instance slightly dissolved away. The tubular impreg nations in the stony layers of the formation appear to be marke off from the mass of the rock so as to sometimes weather oı like casts of fucoid stems. In other instances they appear lil slightly more colored parts of the rock. The thread-like exte sions of green clay which form a network in the dark shale some horizons where it comes in contact with the lighter sha vary in coarseness at different places. There is nothing to inc cate a structural boundary between the green in the threads aı their dark matrix, and there is hardly anything to suggest th they have an organic origin. It seems more likely that th have resulted from some progressive change in the mineı nature of the shale. Excepting the lingulas, the fossils whi occur in the layer numbered 6 in the general section are all ol black and bituminous substance, which is apt to break and f out in drying, leaving only a mold. The dark shale in numbe 6 and 7 is fine and very uniform in character. Occasional it is difficult to distinguish from the Coal Measure shale, b the latter usually contains small mica scales, which are abse from the former. Where not weathered, these beds contain considerable amount of bituminous material, which on distillati yields inflammable gas and oil. The several layers of t formation have been examined for phosphate by Dr. J. Weems, who finds 2.01 per cent. in number 7, 1.94 per cent. number 6, 2.09 and 2.18 per cent. respectively in two analyses material from number 5, 3.18 per cent. in number 4, 6.82 an 5.29 per cent. respectively in two analyses of material froı number 3, 5.43 per cent. in number 2, and 4.86 per cent. i number 1.

Structural Relations.—As already shown, a pronounced uncoı formity separates this formation from the overlying Coal Mea ures. The erosion interval preceding the deposition of tl latter has left its marks, not only in the reliefs which exteı from the top of these beds to a considerable distance belc their base into the underlying limestone, but also in the weat ering of the Sweetland Creek beds, especially where these ri

high. In such places the lamination appears indistinct, and the shales are oxidized and leached. After the deposition of the Sweetland Creek beds they were raised and subjected to erosion and sculpturing, which no doubt removed the greater part of them. Only remnants are left. Then, again, the land was submerged, and the topography just sculptured was covered over by the variable shore deposits of the Coal Measures.

It has also been shown that there is an unconformity with the underlying Cedar Valley limestone. But this unconformity indicates altogether different conditions. The upper formation is, in this case, not a shore deposit. The basal member of the Sweetland Creek beds is a thin layer of argillaceous dolomite containing no littoral detritus, and it is unusally uniformly developed, though only two or three inches thick. It is a sediment made in the sea at such a slow rate that the teeth of dying fishes accumulated rapidly enough to make at one place as much as one fourth of its bulk. This layer follows the small inequalities in the surface of the lower rock like a mantle. None of these are very high or deep. On a distance of a few rods none appear to exceed two feet in vertical extent. Near the Geneva school the basal tooth-bearing layer appears to occupy a place eight feet lower than the highest ledge in an abandoned quarry close by. The surface of the limestone is, however, plainly eroded and apparently to some extent oxidized. In the east bank of Sweetland Creek the highest ledges of the limestone run out to the south, and the overlying formation comes down over their beveled edges. An unconformity of this kind is most likely caused by subaqueous erosion, due to marine currents, followed by renewed sedimentation in the same sea. Such events may have been accompanied by an approach of the shore line. This is, perhaps, indicated by the presence of faint traces of vegetation in the later member in this case. But at the very beginning of the second accumulation the shore was not near enough to leave a trace of anything coarser than clay. Even this was scarce at first, when calcareous sediments predominated. The persistence of each thin layer over distances of several

miles goes to show that the conditions under which they were laid down were uniform over wide areas, and such conditions are not to be found in the proximity of the shore line. Everything considered, this unconformity was most likely caused by changed conditions in the sea and its currents, in all probability consequent upon some orogenic movements affecting the ocean basin.

Fossils.—The fossils so far found in this formation are few, but they are many enough to indicate that it must be referred to the Upper Devonian, or the Chemung. The fibrous plant-like impression from number 3 was found extending over a slab a foot long and about three inches wide. In the pyritous layer in number 2 there was a similar, much smaller, impression. The mold in both instances was covered by a bituminous crust an eighth of an inch in thickness. In this no organic structure could be detected. The lingulas which occurs in numbers 3 and 6 have been submitted to Dr. Charles Schuchert, who says that one species is apparently identical with an undescribed species, from nodules in the "Black Shale," or the Genesee; one is related to *L. melie* Hall, from the Cuyahoga shale; and another to *L. nuda* Hall, from the Hamilton. The author has also observed one lingula in number 6, which resembled *L. subspatulata* M. and W. Some small bilobate fossils from the same number in the general section have been examined by Dr. J. M. Clarke, who has reported that they are identical with *Spathiocaris emersoni* Clarke. This fossil occurs in the Portage group in New York, and has not previously been reported from the West. In the same layer the author found one fossil which resembled *Solenocaris strigata* Meek. This form is known to occur in the "Black Shale" of the Ohio valley. The cast of a gasteropod, found in the stony ledge number 3, was too fragmentary for more exact determination. Dr. C. R. Eastman has examined all the fish remains found, and states that the greater number of the teeth from numbers 1 and 2 are *Ptychtodus calceolus* M. and W. He finds them on the average smaller than usual, but in other respects perfectly like the type. He also reports that there are several other forms of flat, crushing teeth, which are allied to

Synthetodus from the State Quarry fish bed in Johnson county. From the bituminous dark shale, number 6, he identifies a Rhynchodus, related to *R. excavatus* Newb., from the Hamilton in Wisconsin.

LIST OF FOSSILS IN THE SWEETLAND CREEK BEDS

Impression of plants.	
Lingula, sp. undet.	Identical with one from the Black Shale
L. cf. melie Hall	Cuyahoga Shale
Lingula, cf. nuda Hall	Hamilton
Lingula subspatulata M. and W. (?)	Black Shale
Spathiocaris emersoni Clarke	Portage Shale
Solenocaris strigata Meek (?)	Black Shale
Gasteropod	
Ptychtodus calceolus M. and W.	Hamilton and State Quarry Beds
Synthetodus	State Quarry Beds
Rhynchodus, cf. excavatus Newb.	Hamilton

Additions will no doubt be made to this list. As it is, it indicates a correlation with the Upper Devonian of New York, and more particularly with the Devonian Black Shale of the interior, which also is regarded as a part of the Upper Devonian. To this shale it shows another resemblance in having the basal layers stony and containing a comparatively high per cent. of calcium phosphate, while the upper part is a black shale. It will be remembered that in Perry and Hickman counties in Tennessee the Black Shale changes downward into the phosphate rock.[1]

This comparison may be better shown in tabular form.

RELATION OF DARK SHALE TO PHOSPHATE BEARING ROCK IN IOWA AND IN TENNESSEE

Iowa		Tennessee
Bed No. 7 contains 2.01 % of phosphate	Dark Shale	Black Shale containing little or no phosphate
" " 6 " 1.94 % " "		
" " 5 " 2.13 % " "		
" " 4 " 3.18 % " "	Variable beds	
" " 3 " 6.05 % " "	Greenish gray pyritiferous rock and shale	Light gray to bluish-black phosphate rock, with disseminated pyrites
" " 2 " 5.43 % " "		
" " 1 " 4.86 % " "		

[1] See the Tennessee Phosphates, by C. W. HAYES, Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

The indicated correlation appears all the more probable, as there exists under the phosphate-bearing rock in Tennessee an unconformity, which is believed to be due "not to the existence of a land area and subaërial erosion, but rather to non-deposition, by reason of strong marine currents."[1] The renewal of the conditions of sedimentation in the paleozoic sea in the late Devonian age may not have been quite simultaneous in the two localities, though nothing is known to indicate the contrary, but there seems to have been at any rate a parallel in the sequence of events.

J. A. UDDEN.

[1] Loc. cit., p. 534.

STUDIES IN THE DRIFTLESS REGION OF WISCONSIN

In my previous articles under the above title I have stated that no glaciated material had up to that time been found. Indeed I was not very hopeful that any would be found, for not only are the beds concealed to a very large extent, but the parts exposed are those which would naturally be composed of superglacial and englacial material. Add to this the fact that the glaciers if really prescribed, were but a few thousand feet long at the utmost, and the further fact that even of this short distance a considerable portion was over loess of earlier deposition and it will be seen that such material must necessarily be scanty. Nevertheless in view of the extreme difficulty of determining the original aspect of the beds in many important particulars it was very desirable that the evidence which could be furnished by glaciated material should be added to that already given. I think it very fortunate therefore that during the past summer I have discovered a bowlder which gives very strong if not decisive indications of glacial abrasion, and inasmuch as it will form a most important part of the evidence for the existence of glaciers I will describe it in considerable detail.

The bowlder lies at the bottom of a ravine, well within one of the smaller valleys. It is about 10 in.×14 in.×26 in. in dimensions. The material is a rather hard, course-grained ferruginous sandstone, such as occurs a little below the base of the Lower Magnesian limestone. Its rather rough uneven surface is the product of prolonged weathering, but at one end there is a facet forming an irregular oval about 6 in.×8 in. which contrasts strongly with the rest, being nearly flat, and very noticeably smoother to the touch. Examination with a lens shows that this smoothness is due to the relatively small projection of the individual sand grains, few standing out more than a third of their diameter above the general surface, while on the

weathered portions they often project nearly their entire diameters.

It is evident that the resistance of the sand grains to abrasion was greater than the strength of the cementation, so that the abrading agent removed them integrally instead of wearing them down to a common surface. There is, however, near one edge of the facet a small concretionary nodule within which the great abundance of iron furnishes a strong cement. In this the individual grains *are* worn to a common surface, the effect being equal to the best examples of glacial polish. A portion of this concretion passes over onto the weathered surface where the grains are all entire, and owing to the strong cementation many of them are held as the capping of little pedicels, giving a very rough surface. The bedding plane of the bowlder is parallel to its longer diameters, and the flattened facet is nearly perpendicular to this. The facet is crossed in a direction perpendicular to the bedding plane by a straight groove about ¼ in. wide and deep enough to render it perfectly distinct. Other markings are but faintly shown, but so far as they are distinguishable they are parallel to the groove.

It appears quite evident that this abraded facet was superimposed on an originally weathered surface, for sundry depressions occurring within it were not affected by the abrasion, but still retain their original weathered character. Taking all these features into consideration I think it may be said that they are such as are characteristic of glacial abrasion, while it is hard to suggest another agent by which they could have been produced. Certainly none which we have the least reason to believe was operative in the locality.[1]

I have mentioned that the bowlder lies at the bottom of a ravine. It may therefore be well to add that although it is exposed to the action of the occasional torrents, yet the facet in question is turned away from them, while that portion which

[1] It would seem that abrasion of this kind and extent might be within the competency of the friction to which ordinary talus is liable to be subjected in descending a slope.—Ed.

does receive their impact (and has certainly for a long time) is indistinguishable from the rest of the weathered surface. But the results of torrential abrasion are so different from those described that it need not be seriously considered as a possible agent.

If this be a case of glacial abrasion, and it is difficult to resist such a conclusion, it must necessarily decide the question as to the existence of small local glaciers, since its situation is such that if glaciated at all it was certainly the work of such local glaciers.

It was my hope during the season just passed to make a series of observations at critical points with a view to a more definite determination of certain doubtful features, but owing to a pressure of other work they were for the most part left incomplete. On two points, however, evidence of considerable value was obtained. The first relates to the frontal characteristics of the bowlder beds, especially the frontal slope. This appears to have been normally steep as compared with the portion immediately back of it along the axis of a valley.

This characteristic is shown in two or three of the beds which fail to reach the present river level, but as they fall within the limits of the highest terrace it is open to question whether the effect was not due to erosion when the river was at that stage. But I have ascertained that the same characteristic is found in beds which terminate a hundred feet or more above this level. Still another bed extends to the present river level and has been truncated by river erosion, but gives no indication of erosion at the higher level, although by situation it was especially exposed to erosive action — far more so than the other beds which were well protected from currents.

The second relates to the disposition of the beds along the sides of the valleys showing that on reaching their rocky sides the beds rise to higher level than along the axes of the valleys, This is not hillside wash since the material is foreign to the hills on the sides of which it occurs.

Assuming these beds to be glacial an interesting question is

raised as to their synchronism with the successive phases or epochs of the glacial period.

Before this can be answered other than conjecturally it will be necessary to correlate them with the succession of non-glacial deposits filling the larger valleys of the driftless region, a work of considerable difficulty.

G. H. SQUIER.

A DISCUSSION AND CORRELATION OF CERTAIN SUBDIVISIONS OF THE COLORADO FORMATION

A FAIRLY accurate correlation of the subdivisions of the Colorado formation in the central-interior province is not difficult. Although the work done in the different areas of the province has been largely independent, yet divisional lines are not strikingly inharmonious. Points of separation are more easily determined in certain areas than in others. In specific parts of the province confusion in regard to divisional lines seems to have arisen, due to misinterpretations of a palæontological nature, while in other parts the confusion seems to be due to lithological similarities. The points involved are, on the whole, minor ones, and, perhaps, are not worthy of any very elaborate discussion. Nevertheless, stratigraphical geology is, at its best, complex, and therefore should receive every additional contribution which will tend to relieve its comlexity.

The Colorado formation has not been studied as thoroughly and systematically as is desired, yet a study has been made of a sufficiently large number of areas to warrant the establishment of more general division lines. The areas of the central-interior province which have been studied somewhat in detail are: The southeastern Colorado area, the Black Hills area, the eastern Dakota area, the Iowa-Nebraska area, and the Kansas area. Since I am more familiar with the detailed stratigraphy and palæontology of the last-named area I will discuss it and use it as a standard by which to correlate the other areas.

In the Kansan area two principal groups have been recognized for the Benton series. These groups are, the lower or Limestone group and the upper or Shale group. The division is based primarily on lithological grounds as the names indicate. The Limestone group admits of five subdivisions, such divisions

being made on either palæontological, lithological or economic conditions. The subdivisions are: The Bituminous Shale, the Lincoln Marble, the Flagstone Beds, the Fencepost Beds, and the Inoceramus Beds. The Shale group has two divisions, the Ostrea Shales and the Blue Hill Shales. The Niobrara series is divided into the Fort Hayes Limestone and the Pteranodon group, the latter being further divided into the Rudistes Beds and the Hesperonis Beds.

FORT BENTON

The bituminous shale.—Although I have named these beds as one of the subdivisions of the Limestone group I prefer to discuss them separately for convenience of correlation. The Bituminous shale is a moderately compact argillaceous shale which in some localities is somewhat calcareous. The prevailing color of the shales at the base of the beds is dark blue, which passes to light gray at the upper limit. The beds contain the remains of a marine fauna, since plesiosaurs' bones, sharks' teeth, and impressions of Inoceramus are found in them. The maximum thickness of the stratum is not more than twenty-five or thirty feet.

In the Arkansas valley in Colorado its stratigraphical equivalent, the Graneros shales,[1] reach a thickness of 200 feet. In the Huerfano area[2] these shales have a thickness of 100 feet. Near Sioux City, Iowa, and Ponca, Nebraska,[3] a bed of shales, having a thickness of forty feet, occupies the same geological horizon and possesses primarily the same characteristics. In the Black Hills area near Buffalo Gap these shales have a thickness of more than twice that of the Eastern area, being in the neighborhood of 100 feet in thickness. The stratum appears to be very persistent, occurring in all the known areas of the cen-

[1] GILBERT, G. K., The Underground Waters of the Arkansas Valley in Eastern Colorado, Seventeenth Ann. Rept. U. S. Geol. Surv., 1896.

[2] STANTON, The Colorado formation and its Invertebrate Fauna, Bull. U. S. Geol. Surv., 1893.

[3] CALVIN, The Relation of the Cretaceous Deposits of Iowa to the Subdivisions of the Cretaceous proposed by Meek and Hayden, Am. Geologist, Vol. XI.

tral-interior province. And although it varies much in thickness its faunal and lithological characteristics are remarkably uni form.

The Limestone group.—The Limestone group is recognized in all the areas except the Iowa-Nebraska and Eastern Dakota areas. Subdivisions have not been designated for the group in any of the areas except the Kansan. Although the subdivisions are persistent the divisional lines are arbitrary for the beds grade into each other. The Lincoln Marble is more easily differentiated on both palæontological and lithological grounds. It has a remarkably interesting and unique fauna. In the shallow marine waters where its beds were deposited, foraminifera, corals, and oysters were associated with sharks, fish, turtles, and saurians. The rock is composed almost wholly of foraminiferal remains, in which are imbedded sharks' teeth, fish teeth, shells, and other animal remains. So abundant are the teeth in certain portions of the rock that it gives a reddish hue to the surface on which they have been rendered visible by weathering.

The beds are composed of thin layers of a compact close-textured limestone, having an average thickness of three or four inches, and susceptible of moderate polish. On account of the last-named characteristic it is called, locally, marble. The limestone layers are separated by thin beds of shale of about the same thickness. The assumption that these beds are of shallow water origin is based on the presence of quantities of carbonaceous matter in the limestone and the highly carbonaceous character of the intercalated shale beds. Numerous fragments of fossilized trees and charcoal have been discovered in the beds in the Kansan area.

The Lincoln marble is notably persistent in the Kansan area. The same is true of the Black Hills area. In the latter area the layers of limestone are somewhat arenaceous, but the faunal characters are similar, as fish teeth and saurian bones have been noticed. It is presumable that when a careful study is made of the Benton stratigraphy in other parts of the province that the Lincoln marble will be differentiated. Such is not so likely to

be true in the case of the other subdivisions of the Limestone group, since the criteria are not so pronounced.

In the Iowa-Nebraska area, according to descriptions given of that region, the Benton limestone group seems to be entirely wanting. This may be due to a misunderstanding in regard to the proper position of the division line between the Benton and the Niobrara. The following is a description of the Benton in that region.[1] "Shales are more or less unctuous to the feel, somewhat variable in color and texture, containing remains of saurians and teleost fishes, the upper beds sometimes bearing impressions of *Inoceramus problematicus;*" while the Niobrara which rests upon the above described Benton shales is described as follows: "Calcareous beds consisting of chalk and thin bedded limestones, containing shells of *Inoceramus problematicus, Ostrea congesta,* and teeth of *Odotus, Ptychodus,* and other selachians; thickness, thirty feet."

It is not improbable that a part of these thirty feet of so-called Niobrara should be assigned to the Benton, since, in speaking further of the beds, the author says: "These (beds) consist in part of soft chalky material and in part of fissile limestone that divides under the hammer or on exposure to the weather, into relatively thin laminæ crowded with detached valves of *Inoceramus problematicus.*"

The above describes exactly the Inoceramus beds of the Benton in the Kansan area. In that area *Inoceramus labiatus*, syn. *problematicus*, makes its appearance in the upper Bituminous shale beds, and continues to increase in numbers until the Inoceramus beds are reached, where it attains the acme of its abundance. It then declines in numbers to the Blue Hill shale horizon, where it disappears altogether, and if it reappears at all in the Niobrara it is very rare.

The geological range of the species is confined to the lower Benton, and although its zone appears to be narrow its geological distribution is exceedingly wide, as it is reported from nearly all known Cretaceous areas. Mr. Gilbert[2] mentions it as the

[1] CALVIN, loc. cit.

[2] Loc. cit.

characteristic fossil of the Benton limestone in the eastern Colorado area, and also speaks of its abundance in certain layers. *Inoceramus labiatus* has been confused in certain areas with *I. deformis* and other species of the same genus. This confusion has arisen on account of its reported association with *Ostrea congesta*. *Ostrea congesta* occurs in the Benton, where it is found adhering to a large nearly flat *Inoceramus*, but is never found adhering to the much smaller species, *Inoceramus labiatus*. In fact, it is rarely found associated with that species. *Ostrea congesta* occurs also in the Niobrara. It is here found attached to *Inoceramus pennatus*, *I. concentricus*, *I. platinus*, *Radiolites maximus* and other large shells. *Inoceramus sp.*, to which the ostreæ of the Benton are attached, resemble *Inoceramus platinus* of the Niobrara, but on account of the extreme brittleness of the Benton shell, due to its transversely fibrous structure, whole specimens cannot be obtained for examination.

But there is a distinction between the forms of the adhering ostreæ. *Ostrea congesta*, var. *Bentonensis* is a small thin subtriangular shell which, if permitted to grow uninterrupted, is almost flat. The upper valves are so thin that they are rarely preserved. *Ostrea congesta*, var. *Niobraraensis* is a larger, thicker shell, with the lower valve more capacious, and possessing near the hinge area well-marked vertical lines of muscular attachment. The upper valve is also thick, and in many specimens possesses adhering forms of the same species. The differences may not be marked enough to be considered specific differences, but they are sufficiently well developed to distinguish the two forms. It is well to bear in mind then that there is a species of *Inoceramus* in the Benton which possesses adhering forms of ostreæ, and that there is a similar species in the Niobrara possessing them, and that therefore *Ostrea congesta* adhering to *Inoceramus* cannot be taken as a criterion for either group unless the ostreæ are properly differentiated.

The shale group.—Resting upon the limestone group is a bed of shales called the Ostrea shales on account of the abundance of that fossil in them. These shales are argillaceous, so much

so in places that they might with propriety be called clay, and are variable in color. The prevailing color is dark blue. Here and there in the shales are thin beds of limestone containing *Inoceramus labiatus* and species of cephalopods. *Ostrea congesta*, var. *Bentonensis* attached to *Inoceramus sp.*, is the most abundant species. Fish teeth, sharks' teeth, and pavement plates and fossil wood containing species of *Parapholæ*, also occur. Near the upper limit the shales contain a species of *Inoceramus* with *Serpula plana* attached. The thickness of the Ostrea shales in the Kansan area is 150 feet. They are the stratigraphical equivalent of the lower Carlile shales in the eastern Colorado area. The Black Hill area possesses a bed of shales twenty or thirty feet in thickness, which is stratigraphically and palæontologically equivalent to the Ostrea shales. Specimens of *Serpula plana* and *Inoceramus labiatus* were found in an outcrop of the shales on Hat Creek, a southern branch of the Cheyenne River. The Ostrea shales in this area are somewhat arenaceous, and the prevailing colors are blue and light yellow. The Ostrea shales are wanting in the Iowa-Nebraska and eastern Dakota areas.

The Blue Hill shales.—The Blue Hill shales form the upper zone of the shale group. They are dark or slaty colored shales which, under the influence of weathering, break up into very fine, chaff-like fragments which are so light as to be moved about somewhat easily by the wind. On account of their fine, laminated appearance the shales are sometimes called paper shales. They are unfossiliferous and homogenous, except in the upper third. This zone has numerous argillaceo-calcareous concretions called septaria imbedded in its shales. Some of these concretions possess the cone-in-cone structure, while others are formed of concentric layers. Fissures in others of the concretions have been filled in by sedimentation with calcite which ranges in color from white to claret. These are the true septaria. Many of the concretions are highly fossiliferous. The following species have been collected from them: *Scaphites larvæformis*, *S. vermiformis*, *S. warreni*, *S. ventricosus*, *S. mullananus*, *Rostellites willistonii*, *Pri-*

onocyclus Wyomingensis, *Placenticeras placenta*, *Inoceramus undabundus* and *I. tenuirostratus*.

In the Kansan area the Blue Hill shales have a thickness of 100 feet. The upper Carlile shales form their stratigraphical equivalent in the Colorado area. The septaria zone occurs in relatively the same position in the Carlile shales, and presents approximately the same lithological characteristics. The total thickness of the Carlile shales is from 175 to 200 feet, including the upper and lower beds, the equivalents of the Blue Hill and Ostrea beds. In the Black Hills area a bed of shales thirty to forty feet in thickness, bearing calcareous concretions of the cone-in-cone structure is the stratigraphical equivalent of the Blue Hill shales. The Blue Hill shales as well as the Ostrea shales have no equivalent in the Iowa-Nebraska and eastern Dakota areas.

THE NIOBRARA

The division line between the Benton and the Niobrara in the Kansan area at least is not an arbitrary one. Lithologically it marks a change from dark argillaceous shale to comparatively pure chalk of remarkable whiteness, scarcely compact enough to deserve the name limestone. The change is one of abruptness, there is no transition zone. The shale does not appear again. A massive stratum of limestone rests upon the dark shales, and there is no intermediate layer, part chalk and part shale. Palæontologically the change is marked by the ushering in of an almost entirely new fauna.

Two principal divisions of the Niobrara are recognized in the Kansan area. These are the lower or Fort Hays limestone and the upper or Pteranodon beds. The division may be said to rest on both lithological and palæontological grounds. The Pteranodon beds are further subdivided into the Rudistes and Hesperonis beds. This division is made on purely palæontological evidences.

The Fort Hays limestone.—The Fort Hays limestone is in massive layers of from two to four feet in thickness, and the

total thickness of the bed is fifty to sixty feet. When taken from the quarry it is very soft and easily cut and carved into any desired shape. It hardens somewhat on exposure. The lower portion, except for the minute cocoliths and foraminiferæ is largely unfossiliferous. The upper portion contains many species of invertebrates.

In the Colorado area the lower fifty feet of the Timpas beds is the equivalent of the Fort Hays. The zone is described as being composed of layers of a compact, rather fine-grained limestone of a light gray color which becomes creamy white on weathered surfaces. The layers are from a few inches to three feet in thickness, and are separated by thin beds of shale usually one or two inches thick.[1]

In the Black Hills area the position of the Fort Hays is occupied by a bed of shales containing a layer of limestone two feet in thickness. In the Iowa-Nebraska area it seems probable that the Fort Hays beds rest upon the Benton limestone, but the line of separation may be difficult to establish. In the eastern Dakota area the equivalent stratum reaches a thickness of 130 feet.

The Pteranodon beds.—The upper division of the Niobrara comprises the true chalk of the Kansan area. The chalk varies in color from a light blue through lavender, yellow, and buff, to red and orange. Under fresh exposure it presents the appearance of a blue shale, and has often been taken for such. The freshly exposed beds, however, under the weathering influence of air and water, soon change their shale-like appearance and blue color. The change in color is probably due to a chemical change in the iron compounds in the chalk. Chert beds occur in some places interstratified with the chalk. These are only of very local occurrence, however. The chalk is used to some extent as a mineral pigment in the manufacture of paint. Fossil wood is not of rare occurrence in the chalk, and it is frequently found pierced with the shells of *Parapholæ*. Fragments of amber[2]

[1] GILBERT, loc. cit.

[2] WILLISTON, The Niobrara. Kan. Univ. Geol. Surv., Vol. II.

have been obtained from some of the specimens of fossil wood. Charcoal also occurs in the chalk as well as in the Benton limestone. Nodules of pyrite are abundant in some outcrops.

The lower Rudistes beds present a varied and extensive invertebrate fauna. The Hesperonis beds contain fewer invertebrates, but a vastly greater number of vertebrates than the lower Rudistes beds.

The upper 125 feet of the Timpas beds is probably the equivalent of the Rudistes beds, while the Apishapa beds are the equivalent of the Hesperonis beds in the Colorado area. In the Black Hills area the position of the Pteranodon beds is occupied by a bed of shales with a thin bed of limestone. The beds are wanting in the Iowa-Nebraska and eastern Dakota areas. In the following table, which is intended to show the relation of the different subdivisions in the representative areas, the eastern Dakota area is omitted, as it does not differ materially from the Iowa-Nebraska.

		Kansas area		Colorado area		Black Hills area	Iowa-Nebraska area
THE COLORADO FORMATION	NIOBRARA SERIES	Pteranodon beds, 275′	Hesperonis beds, 150′	Apishapa beds, 200′		Shale, limestone, 150′	Wanting
			Rudistes beds, 125′	Upper Timpas, 125′		Shale, limestone, 200′	Wanting
		Fort Hays limestone, 50′ to 60′		Lower Timpas, 50′		Limestone, 2′ to 4′	Chalk, limestone, 40′
	BENTON SERIES	Shale group, 250′	Blue Hill shales, 100′	Carlile shale, 200′	Upper Carlile	Shale, 30′ to 40′	Wanting
			Ostrea shales, 150′		Lower Carlile	Shale, 20′ to 30′	Wanting
		Limestone group, 40′ to 50′		Greenhorn limestone, 25′ to 40′		Limestone, 10′ to 15′	Wanting (?)
		Bituminous shale, 20′ to 40′		Graneros shale, 200′		Shales, 100′	Shales, 40′

W. N. LOGAN.

EDITORIAL

THE December number of the *Astrophysical Journal* gives a translation of a paper "On the Constitution of Gaseous Celestial Bodies," by A. Ritter, which possesses much geological significance if its general conclusions are trustworthy. The original paper is one of a series of eighteen which appeared between the years 1878 and 1883 in Wiedemann's *Annalen*, but its astronomical and geological bearings appear to have escaped the attention they merit, and for this reason it is now reproduced. Ritter attempts to compute the time which would be occupied by a gaseous solar sphere of the dimensions of the earth's orbit in contracting to the dimensions of the present sun; in other words, the time of evolution of the solar system from the separation of the earth to the present stage under the Laplacean hypothesis, with certain qualifications. The computation is necessarily based on certain assumptions, some of which require modification in the light of more recent investigations, but any competent attempt at a mathematical discussion of the rate of solar evolution under the gaseous hypothesis constitutes a notable contribution to the cosmical phases of geology. The conclusion is reached that about 5,500,000 years ago the solar radius was equal to the radius of the earth's orbit. On the assumption that the effective radiating disk of the sphere was always equal to the whole disk, Ritter concludes that the solar mass shrank from dimensions of the earth's orbit to a dimension ten times the present sun's diameter in the remarkably short period of 255,710 years. On the assumption that the effective radiating disk was half of the whole disk, he finds that a similar shrinkage would take 511,420 years. In the latter case the total time occupied by the solar mass in contracting from the earth's orbit to its present dimensions would be about 5,765,000 years. This con-

clusion is based on the assumption that the thermal capacity was 1.41. On the assumption that it was five thirds, which is the largest permitted by the mechanical theory of heat, the conclusion is reached that the contraction could at most have occupied about 6,500,000 years.

The foregoing computations are based upon Pouillet's estimate of the present radiation of the sun. If the computation be based on recent estimates, which give a rate at least 50 per cent. greater, the resulting time is about 4,336,000 years. Ritter recognizes that the departure of the body from a spherical shape arising from rotation would modify the results, as these were based on the assumption of a spherical form throughout the whole period, but as this departure was large only during the comparatively small portion of the whole interval occupied in the contraction from the earth's orbit to twice the sun's present diameter, the correction is limited, but yet may be considerable. In view of this the author remarks: "For these reasons we cannot give the maximum value $t=4,336,000$ years found above the significance of a superior limit for the age of the earth, the less in fact since the original assumptions must still be regarded as hypotheses imperfectly satisfied. Nevertheless it seems permissible to conclude from the above investigation that the actual age of the earth must be far less than the estimates of some geologists, who place it at hundreds of millions of years."

Whatever corrections may be applicable to such a computation, the attempt to subject the time factor of the gaseous hypothesis of the evolution of the solar system to rigorous mathematical inquiry is a most helpful one. The discussions of Lord Kelvin and others who have attempted to assign limits to the age of the earth by merely determining the maximum amount of heat which the sun can have radiated in the past, on the gravitational hypothesis, do not really get home to the question, since they do not determine the rate of radiation of heat in the past. If that rate were faster than the present rate it is obvious that the time would be correspondingly shortened; if

slower, it would be correspondingly lengthened. This radi
defect is obviated, in the main, by Ritter's method.

If the period occupied by the supposed gaseous ancestor the sun in shrinking from the earth's orbit to its present size such as computed by Ritter, or if it be any period of that or of magnitude, it will probably be the conclusion of geolog and biologists that the hypothesis of such a gaseous sur irreconcilable with geological evidence and with the phenom of biological evolution. At any rate, this is a mode of test the validity of the gaseous hypothesis which merits the car consideration of those competent to pass judgment upon it, it is earnestly to be hoped that the method of Ritter and assumptions will be subjected to critical reëxamination in light of the most recent researches.

The press announce that in a recent lecture before the L ell Institute, Dr. See stated certain radical conclusions wh he has reached with reference to the temperatures of exteriors of gaseous bodies. We understand that his fun mental formula is closely analogous to one of those derived Ritter. Applied to the sun when expanded to the dimensi of the earth's orbit, it gives a relatively low external temp ture. It is not clear that this low outer temperature is comp ble with the rapid loss of heat that appears to be invol necessarily in Ritter's rapid evolution, and we do not underst that Dr. See holds the latter view. Geologists will watch v interest the appearance of Dr. See's new views in authentic fo and may well congratulate themselves on the prospect of a cussion of the nebular hypothesis on new lines.

T. C. C

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THE eleventh annual meeting of the Geological Society America, which was held at Columbia University, in New Y City, was characterized by a large attendance of the Fellows by a very general interest in the proceedings. The accommo tions furnished by the University were sumptuous in many w the elegant Schermerhorn building proving highly satisfact

except for the acoustic properties of the large lecture hall. The opportunities for luncheon were adequate and agreeable. The social features of the meeting, consisting of receptions at the American Museum of Natural History and at Professor Osborn's residence, and the annual dinner, were eminently successful. The dinner was pronounced the most satisfactory yet enjoyed by the society.

The program was varied and attractive, no one branch of the subject being greatly in excess of others. General geology, stratigraphy, physiography, glacial geology, palæontologic geology, and petrology were each represented by able exponents. But to those who attempted to follow the programs, it was evident that the shortness of the time devoted to the meetings, together with the length of the program of a well attended session, necessitate a better regulation of the proceedings than it has heretofore been the custom of the presiding officers to enforce. The evident hesitation on their part to interfere with the presentation of papers by Fellows of the society, while agreeable to the individual at the time, is not conducive to the best interests of the society as a whole, that is to say, to the other Fellows in general. Interference may properly be exercised in the case of those who exceed the time allotted them for the presentation of papers, especially since in most instances the time is that determined by themselves.

There should also be some rule limiting debate both as to length and matter. The exhibition of lantern views is a most valuable aid to the presentation of many subjects, which was very well shown at the meeting just held, but the selection of illustrations should be limited to those which actually illustrate the subject, and should be made to avoid unnecessary repetition.

The result of these abuses, the overrunning of time in presentation and discussion, and the introduction of unnecessary illustrations, is the crowding of papers on the last day of the meeting, the consequent haste in their delivery or the curtailing of considerable parts of them, and a general sense of dissatisfaction; first, with those who said too much, and last, with those

who said too little. The correction of these evils should r with the presiding officers, but must originate with the Fello themselves. It is to be hoped that some regulations will formulated and put into operation at the next winter meeting Washington, D. C.

J. P. I

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IN an article on igneous intrusions in the October-Novem number of this JOURNAL, Professor Iddings states that, "R sell has called attention to what he considers volcanic pl in the region of the Black Hills of South Dakota." I de to deny the statement that the intrusions referred to w called *volcanic* plugs; abundant evidence was, I think, preser to show that they are, as I termed them, *plutonic* plugs. T are intrusions of igneous magmas forced upwards into h zontally stratified rocks so as to raise domes above them; did not reach the surface, and hence should not be considere occupying the conduits of volcanoes, and so far as can be jud did not expand laterally after the manner of laccoliths. only one such intrusion was described, but several in var stages of exposure by erosion, from an unbroken dome of st fied beds, presumably with an intruded plug beneath, represe by Little Sun Dance Hill, to the imposing fluted column of M Tepee, over 600 feet high. Associated with these plug-intrusions are what appear to be true laccoliths, as Warren P for example. When this instructive region is more thorou explored, we may expect to find a series of examples illustra the transition from plug-like to cistern-like intrusions or la liths. For these reasons it is well to hold the locality refe to, as furnishing the type-group of plutonic plugs.

The evidence just referred to was stated in the article[1] c cised by Iddings, but without having seen the intrusions without presenting any new observations concerning them brushes it aside and restates the same kind of evidence for

[1] Igneous intrusions in the neighborhood of the Black Hills of Dakota, GEOL., Vol. IV, 1896, pp. 23–43.

apparent purpose of introducing a high-sounding Greek name in place of the term used by me.

In discarding the evidence of the plug-like character of the intrusions near the Black Hills, Iddings states that it is probable they are central remnants of small laccoliths, for the reason that the prismatic columns of which they are largely composed are vertical, "whereas they should be horizontal in the body of a volcanic plug." Unfortunately for this dictum, the prisms in many true volcanic plugs or necks, like those about Mt. Taylor, New Mexico, described by Dutton, are vertical.

In the same spirit in which Iddings discards the evidence of the plug-like form of the intrusions under consideration, and with equal justice, one might use his own language in reference to the account he himself gives of Mt. Holmes, the new type-example brought forward and of the accompanying, largely ideal diagram; "He has mentioned nothing that demonstrates or even indicates that it possesses the character of a plug;" it might just as well be a laccolith eroded down to the feeding conduit.

The term *bysmalith* which Iddings seeks to substitute for plutonic plug, means simply plug-stone, and may be used with equal propriety for both volcanic and plutonic intrusions, of plug-like form; if one wishes to make this convenient distinction the terms *volcanic bysmalith* and *plutonic bysmalith* would have to be used. I fail to see any advantage in such a clumsy nomenclature. The word bysmalith is so similar to *bathylith*, already in the field and also used by Iddings in the article referred to, that confusion must arise if this rechristening is permitted. It seems to me that American geologists should use their mother tongue whenever it can be made to serve, and usually it will be found rich enough to express all the ideas they may have, instead of searching the dictionaries of the dead languages for more or less accurate translations of plain English terms.

ISRAEL C. RUSSELL.

[The use of the term volcanic instead of plutonic in referring to the intrusions in question was inadvertent; much of the assumed distinction in the use

of the terms being artificial and misleading, the writer has become indifferent in his use of both terms.

Nevertheless, with regard to what Professor Russell has called plutonic plugs in the Black Hills region, it may still be said that "In his description of them he has mentioned nothing that demonstrates or even indicates that they possess the character of a plug. In each case they may be central remnants of small laccoliths."

The question, whether the evidence regarding the nature of the Holmes bysmalith is of the same kind as that offered for the character of the Black Hills intrusions, may very well be referred to our fellow-geologist. J. P. I.]

REVIEWS.

Fossil Medusæ. By C. D. WALCOTT. Monog. U. S. Geol. Survey, Vol. XXX, pp. 1–201, Plates I–XLVII, Washington, 1898.

THIS monograph of the fossil medusæ of the world, is the outcome of a careful study of some 9000 specimens of these organisms from the Middle Cambrian shales of the Coosa valley, Alabama. It was the author's first intention to include his observations upon these fossils in a work upon the Middle Cambrian fauna, but as the fossil medusæ from other geologic horizons and from other parts of the world became involved in the investigation, the present monograph was prepared.

Notwithstanding the evanescent character of these jelly-like organisms, their fossil remains have been preserved in the Lower Cambrian strata of New York and several European localities, in the Middle Cambrian of Alabama, in the Permian of Saxony, and the Jurassic of Bavaria. The Alabama specimens occur as more or less radiately lobed, semi-cherty nodules which weather out from the shales in great numbers.

A new family, *Brooksellidæ,* is founded for the reception of the genera *Brooksella* and *Laotira* from Alabama and *Dactyloidites,* previously described from the Lower Cambrian of New York. Two species of *Brooksella* and one of *Laotira* are described, and the one species of *Dactyloidites* is redescribed, and it is surprising that the details of structure of these ancient "jelly-fish" can be so fully determined. The generic term *Medusina* is used for the designation of all those fossil Medusæ whose true generic relations cannot be fully determined, and in this group are placed the three Cambrian species from Sweden. Some observations are made upon the genus *Eophyton* in which have been placed various trails which may have been produced by the tentacles of floating medusæ dragging upon the mud of the sea bottom, or by floating seaweeds. The remaining pages of the volume are devoted to the descriptions of the European Permian and Jurassic forms.

STUART WELLER.

The University Geological Survey of Kansas. Vol. IV. Paleontology. Part I. Upper Cretaceous. SAMUEL W. WILLISTON, Paleontologist. Topeka, 1898.

It is with much interest that we examine this work on the paleontology of Kansas. Professor Williston and his associates have made a successful effort to produce a work of popular as well as scientific value. The effort is worthy of commendation. The manner in which the subjects are presented cannot fail to make the book useful in many places where a purely scientific work would be of little value.

Professor Williston reviews the work on Birds, Dinosaurs, and Crocodiles; but the most interesting and instructive part of his work is the monograph on the Mosasaurs. While his work is primarily with the Kansas Mosasaurs, he does not confine his study to these, but briefly and concisely covers the whole subject. Here, especially, he has been successful in keeping the interest alive.

The monograph opens with a brief historical summary of the Mosasaurs — their discovery and the publications concerning them. This is followed by their range, distribution, and classification. He refers to the controversies over the relations of these reptiles, and arrives at the conclusion from his own study, that they are entitled to be classed as "an independent group among the *Lacertilia.*" In this connection he quotes the classification proposed by Dr. Baur. The greater part of the monograph is devoted to a careful anatomical comparison and description of these interesting reptiles, many of which the author originally discovered and described. No pains have been spared to make the work complete and useful.

In his systematic descriptions Professor Williston points out a number of facts of popular, as well as scientific interest. The Mosasaurs are described as "varying in length between five and forty feet," a decided reduction in size from the Mosasaurs of the text-books, which are given a maximum length of 100 feet. Another fact which seems to have escaped the notice of former collectors is the deformation of the bones undergone in the process of fossilization, especially in the Niobrara formation. The bones have yielded as if made of plastic material. The deformation has furnished the characters upon which many new species have been based. The author concludes that this will cut out about four fifths of the species that have hitherto been described.

The turtles are described by Professor Williston and Professor E. C. Case, and the microscopic organisms by C. E. McClung.

Mr. W. N. Logan who has done much toward giving us a clear conception of the stratigraphic relations of the Upper Cretaceous, presents an excellent discussion of the invertebrates of the Benton, Niobrara, and Fort Pierre groups. He not only reviews the species hitherto described, but adds the descriptions of many new ones which he has found. His work is admirably arranged, and the species so tabulated, that the whole forms a convenient paper of reference. It is to be hoped that much more work of this kind may soon be done in the great Interior Cretaceous region, that a more definite knowledge of its rich invertebrate fauna may be available.

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THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. III

ROCKS OCCURRING IN DIKES

THE rocks described in the preceding part of this article are cut by numerous dikes of various kinds, ranging from very acid aplites to basic diabases. The last are, as is usual along the Atlantic border, the most numerous; aplites and acid granite-porphyries come next, and finally there is a smaller number of rare and interesting types of alkali-rich dike rocks. These have not yet been fully investigated, but, as the rather large number of specimens in my possession represent apparently the main types, a description of them will give at least an approximate idea of the intrusive rocks of Essex county.

GRANITIC DIKES

Aplite.—Dikes of this rock are confined almost exclusively to the granite areas, at least as far as my observations permit me to judge. They are usually very narrow, only a few inches in thickness, and contact phenomena are not very conspicuous.

Megascopically they are dense and fine-grained, of various shades of light gray, and often showing a few small biotites. In thin section they show no very remarkable peculiarities, being a holocrystalline mass of small anhedra of quartz and alkali-feldspar, the latter usually microperthitic. Micrographic inter-

growths of feldspar and quartz are rather common. C
components are rare, those most often met with being
green hornblende and brown biotite, while colorless diop
less frequent. A few specimens carry titanite and mag
while apatite is seldom seen. These aplites are occasi
coarser-grained, and become microgranites, when they res
closely the granites proper, except that the crystallization
smaller scale, and colored minerals are rare.

The most interesting aplitic dike found is one cutting a
ite exposure near Bass Rocks, Gloucester. It is the same
as that mentioned previously with enclosures of orbicular s
and diorite, and the aplite cuts granite and enclosures impa
The dike is only 6–7 cm wide, and is notable on account of
compound in an anomalous way. The borders, about 2
each side, are of fine-grained white microgranite speckle
small, black biotite and hornblende flakes. This shows
the microscope the usual micrograniti structure and char
Extending down the center is a band, about 2 cm in widtl
dense, almost aphanitic light gray aplite, which shows u
lens only very minute black specks. This in thin secti
very finely granular aggregate of round quartz and alka
spar anhedra, with here and there small shreds of green
blende and pale brown biotite.

The junction between the two facies of the rock in th
specimen is slightly irregular but sharp. Under the micr
it is also seen to be fairly sharp, but the quartzes and fel
of the borders show a tendency to granularity and passa
the aplite which is suggestive of crystallization out of one
and not that due to two injections. This idea of differin
tallization in one magma is also supported by the uniformi
which the aplitic band sustains its central symmetrical p
with reference to the two sides. The highly anomalous
ter of the dike will have been noticed, in that the border
trary to the usual rule, are more coarsely crystalline th
central portion. If we adopt Judd's[1] view of the composit

[1] J. W. JUDD, Q. J. Geol. Soc., Vol. XLIX, p. 536, 1893.

of Arran it is easy to explain this by assuming that the first-formed dike cracked down its center, and that this crack was filled by a later injection, which, cooling rapidly, solidified as aplite. This is not the place to enter into a discussion of the subject, but it may be said that in view of the facts noted above, the similarity in chemical composition of the two portions, and for other reasons, this explanation does not seem to be the correct one, and we are forced to conclude that the dike is due to only one injection. In this case the coarser crystallization at the borders may be due, as Professor Iddings has suggested to me, to the presence of mineralizers derived from the surrounding granite, or, as seems to me more probable, to certain peculiar physical and chemical conditions which I hope to explain in another place.

	I	II	III	IV
SiO_2	77.49	76.44	77.14	77.61
TiO_2	0.25	0.37	0.29	0.25
Al_2O_3	11.89	12.95	12.24	11.94
Fe_2O_3	0.34	0.19	0.29	0.55
FeO	1.12	0.89	1.04	0.87
MnO	trace	trace	trace	trace
MgO	0.09	trace	0.06	trace
CaO	0.45	0.15	0.35	0.31
Na_2O	4.58	4.76	4.64	3.80
K_2O	4.26	4.95	4.47	4.98
H_2O (110°)	....	....	....	trace
H_2O (ignit.)	0.16	0.09	0.14	0.23
	100.63	100.79	100.66	100.54

I. Aplite. Border of Dike. Bass Rocks. H. S. Washington anal.
II. Aplite. Center of Dike. Bass Rocks. H. S. Washington anal.
III. Aplite. Composition of whole dike, two parts of I, one part of II.
IV. Granite. Rockport. H. S. Washington anal. JOUR. GEOL., VI, p. 793, 1898.

Analyses were made both of the border and of the center and are given above in I and II. The composition of the dike as a whole, calculated from two parts of I and one part of II, is given in III. The two parts of the dike are seen to be sensibly identical in composition, the border with a little more silica, lime and magnesia, and a little less alumina and alkalies. The

composition of the dike as a whole is remarkably similar to that of the granite of the region (analysis IV), the only noteworthy difference being in the soda.

Quartz-syenite-porphyry.— Dikes of this are met with in considerable numbers in the granite areas, especially that of Cape Ann, where they have been mapped by Shaler.[1] The best specimens in my possession come from the dikes numbered by Shaler 52, 53, and 70 on Eastern Point, and 245, a short distance north of Squam Light, the last being the freshest. Megascopically they show phenocrysts of alkali-feldspar, hornblende and biotite, and fewer of quartz; scattered through a fine-grained groundmass composed of feldspar, some quartz and specks of ferromagnesian minerals. The specimen from near Squam Light is a rather dark ash-gray, while the others are brownish-gray.

Under the microscope the large feldspars are seen to be microperthitic and are all cloudy and somewhat decomposed. The large hornblendes are ragged in outline and usually slightly altered, brown limonitic flakes being seen at their edges. They are of a peculiar, rather vivid grass-green, resembling that of actinolite, and are quite pleochroic. A few ragged plates of greenish-brown biotite are seen as phenocrysts. The groundmass is granitic and holocrystalline, the quartzes clear and generally interstitial between the feldspars. These are almost entirely of orthoclase or soda-orthoclase, not usually microperthitic, with a few doubtful oligoclases. They show a marked tendency to automorphic development. Irregular shreds of hornblende and biotite, similar to those forming the phenocrysts, are quite common, the former being the more abundant. A few small grains of magnetite and titanite are seen here and there and minute needles of apatite are fairly common.

For analysis the freshest specimen from Dike 245, north of Squam Light, was chosen, the result being given below, with that of the Wolf Hill nordmarkite for comparison.

[1] SHALER, Ninth Ann. Rep. U. S. Geol. Surv. Plate LXXVII.

	I	II	III
SiO_2	68.88	68.36	69.00
TiO_2	trace	trace	0.35
Al_2O_3	14.96	16.58	13.95
Fe_2O_3	0.64	0.90	1.56
FeO	4.64	3.24	2.38
MnO	trace	trace	0.55
MgO	0.37	0.45	0.14
CaO	1.74	1.85	0.49
Na_2O	3.83	3.97	5.67
K_2O	4.97	5.27	5.11
H_2O (110°)	0.06	0.18	....
H_2O (ignit.)	0.24	0.17	0.70
	100.33	100.97	99.95

I. Quartz-Syenite-Porphyry. Squam Light. H. S. Washington anal.

II. Nordmarkite. Wolf Hill, Gloucester. H. S. Washington anal. JOUR GEOL., VI. p. 800, 1898.

III. Lindoite. Frön, Norway. V. Schmelck anal. Brögger: Eruptivgest. des Krist. geb. I, p. 139, 1894.

The composition is rather acid, with high alkalies and rather high lime, with ferrous oxide largely in excess over ferric, and is closely similar to that of the nordmarkite. These dikes resemble in certain ways the lindoites of Brögger, which are acid bostonitic rocks. This is seen from the chemical point of view by comparison of I and III, that of the Essex county rock differing materially only in the slightly higher lime. Mineralogically they also resemble each other closely, though blue arfvedsonite or riebeckite is common in the lindoites, while the hornblende here is a peculiar green with only a tinge of blue. One specimen of lindoite in my possession from Huk in the Christiania Fjord, collected under the guidance of Professor Brögger, shows greenish-brown hornblende with some biotite, and does not differ radically from the present dike rocks. Structurally also the two resemble each other, the groundmass feldspars being quite automorphic in stout tables, the quartz interstitial and the hornblende irregular.[1] We do not, however, find in our rocks the zircon which is so common in the Norway

[1] Cf. BRÖGGER, *op. cit.*, I, Fig. 15, p. 137.

rocks. These dike rocks might then with propriety be called lindoite, but in view of their more porphyritic character and for other reasons they will be referred to as quartz-syenite-porphyry.

In this connection must be described two rocks found cutting the gabbro at Nahant. The one, which occurs at Little Nahant, is fine-grained, scarcely porphyritic, mottled gray, pink and green, and is evidently considerably altered. It is essentially a hornblende-biotite-quartz-syenite, and resembles in most particulars the rocks just described. The feldspar is apparently mostly orthoclase, and the hornblende is of a similar peculiar green, not highly pleochroic, and much of it seems to be secondary. The biotite, which is primary and which occurs in smaller amount, is the most notable feature. It occurs as stout crystals with ragged edges, often partially altered to the green hornblende. Its color is greenish-brown, and the strong pleochroism is very striking and unusual; parallel to the cleavage deep grass-green, perpendicular to this reddish yellow-brown, the absorption in the former direction being much the stronger.

The second rock, which is found at the road-metal quarry at Nahant as narrow dikes and small "schlieren" in the gabbro, is a compact, almost aphanitic, rather dark gray rock without phenocrysts. In thin section it shows a multitude of small isodiametric crystals of biotite having a peculiar light yellowish color and usual absorption scheme. With these are very many small colorless diopside anhedra, which in parts of the slide become more numerous. These, together with many magnetite grains and some small apatite needles, are embedded in a colorless or slightly yellow mass, which between crossed nicols is seen to be composed of tabular orthoclase crystals with fewer of a twinned oligoclase, the mesostasis being in patches either alkali-feldspar or quartz, the latter less abundant. In places the feldspar mesostasis extinguishes simultaneously over large areas and becomes poikilitic in character, and in these areas automorphic feldspar crystals are wanting. The tabular feldspars are in fact best developed and sharpest when surrounded by interstitial quartz, when in feldspar they are much less well

defined and more uncertain in outline. The structure as a whole is a rather peculiar one. The rock would seem to be not very acid and with rather high potash, and its occurrence in connection with the gabbro (which it will be remembered also carries some orthoclase) is noteworthy.

A rock which is essentially an *alkali-syenite-porphyry* occurs as a dike on the southeast coast of Marblehead Neck cutting the rhyolite. It somewhat resembles a minette, though rather more acid. Hornblende is absent, diopside rare, and small stout crystals of biotite abundant. These are usually a peculiar light brown and pleochroic, but some are seen of a pale green, slightly bluish in tone, and with feeble pleochroism. This variety also occurs intergrown with the brown, and may be a bleached form of the latter, but it resembles closely the similarly colored biotite found in some of the granites, especially that of Marblehead Neck itself. The groundmass of alkali-feldspar is granular, much of it being decomposed with formation of kaolin. A few grains of probably secondary quartz are present.

PAISANITE-SÖLVSBERGITE-TINGUAITE SERIES

A small but very interesting group of dike rocks is distinguished mineralogically by the combination of alkali-feldspar and either glaucophane-riebeckite or aegirite. These carry abundant quartz at the acid end of the series (paisanite), little or no quartz in the intermediate members (sölvsbergite), and nepheline in the most basic (tinguaite). This series, it will be observed, corresponds very closely to Brögger's Grorudite-Sölvsbergite-Tinguaite series from the Christiania region.[1] As far as my observations go, these dikes are not very wide, a few feet at the most. Nearly all my specimens are from dikes cutting granite, either on Cape Ann or along the Manchester-Magnolia shore; one specimen only is from the foyaite area of Salem Harbor.

Paisanite.—The only example of this rock which I found is Shaler's dike No. 3, at the extreme southeast corner of Magnolia

[1] BRÖGGER, *op. cit.*, I.

Point, near the water's edge, which was called by him a q
porphyry, and was briefly described by Tarr. It has a wi
ten feet, with a strike of N. 2° E. It is cut by a narrow
of dense black diabase.

The rock is compact, with practically no change in t
throughout its width. Phenocrysts of white or yellowish
feldspar, up to 1.5 cm. in diameter, and smaller smoky b
mids of quartz are thickly sprinkled through a very fine-gr
rather dark blue-gray groundmass. By the action of the
and the sea water, with which most of the dike is cove
high tide, the groundmass has been dissolved, and on the
faces the beautifully sharp and automorphic phenocrysts o
spar and quartz stand out prominently. The feldspars are
prismatic, parallel to the axis *a*; are frequently twinned acc
to the Carlsbad and also the Manebach laws, and show a n
of planes. They will be examined crystallographically la

Under the microscope the sections present a striking a
ance. The sharp quartz phenocrysts are clear, with occa
streaks of minute gas or liquid inclusions, and not infreq
carry rounded inclusions of granular feldspar, or feldspa
glaucophane, like the groundmass; while here and there is
crystals of glaucophane are also seen. The highly autom
feldspars are uniformly microperthite, or microcline-mic
thite, no plagioclase being seen. They are dusty with n
often rod-shaped, microlites of a colorless transparent sub
the nature of which is difficult to determine, and are s
especially at the edges, with limonite. They carry inclus
glaucophane crystals, or small groundmass patches, which
sionally show a well-developed micrographic structure. T
little evidence of magmatic corrosion, especially in the fel
though the quartzes show a tendency to rounded angles an
low embayments.

The groundmass is very fine-grained, and is compo
minute needles of dark greenish-blue hornblende, up to .c
in length, strewn pellmell in a granular mass of feldsp
quartz. Neither magnetite nor apatite was seen, nor

lass present. Along the borders of the phenocrysts, both uartz and feldspar, the hornblende needles are smaller and rowded together, as if pushed aside by the growth of the large rystal, in a manner quite analogous to that described by Pirsson[1] the case of a tinguaite from the Bearpaw Mountains. There no evidence of flow structure in the proper sense of the term.

The hornblende is apparently a glaucophane-riebeckite, idencal with that described elsewhere[2] in a sölvsbergite from Cape an. The extinction angle is small, pleochroism intense; parallel the axes *c* and *b* dark blue-gray; parallel to axis *a* pale yellow. he position of the axes of elasticity could not be definitely etermined, but apparently c lies nearest to *c*, indicating that it a glaucophane.

An analysis of this rock is given below, together with one of he Texas paisanite and one of a grorudite from Norway. The aisanites were discovered by Osann as dikes in Transpecos, Tex., and named after the Paisano Pass, where the types were ound. They are composed of quartz, alkali-feldspar, and riebeckite, in the Texas rocks this last forming blue spots in a white groundmass, and quartz and feldspar being also phenocrystic.

	I	II	III
SiO_2	76.49	73.35	74.35
TiO_2	trace	....	....
Al_2O_3	11.89	14.38	8.73
Fe_2O_3	1.16	1.96	5.84
FeO	1.56	0.34	1.00
MnO	trace	....	0.22
MgO	trace	0.09	0.07
CaO	0.14	0.26	0.45
Na_2O	4.03	4.33	4.51
K_2O	5.00	5.66	3.96
H_2O (110°)	0.12	....	....
H_2O (ignit.)	0.38	....	0.25
	100.57	100.37	99.38

I. Paisanite, Dike 3, Magnolia. H. S. Washington anal.

II. Paisanite, Mosquez Canyon, Transpecos, Texas. A. Osann. Tsch. Min. Pet. Mitth. XV, p. 439. 1895.

III. Grorudite, Varingskollen, Norway. Särnström anal. Brögger, *op. cit.*, I, p. 48, 1894.

[1] Pirsson, Am. Jour. Sci. (4), II, p. 191, 1896.

[2] H. S. Washington, Am. Jour. Sci. (4), VI, p. 177, 1898.

The analyses of the two paisanites resemble each other closely, the main differences being in silica, alumina, and ferrous oxide. These rocks are analogous to the grorudites of Brögger, which, however, carry aegirite in place of soda-hornblende, and which are rather less acid than the Magnolia rock. The replacement of alumina by ferric oxide in the grorudite is to be noticed. The phenocrysts differ also in being alkali-feldspar, aegirite, and hornblende, while quartz occurs only in the groundmass, and the color of the rock is dark green, rather than blue, owing to the abundant aegirite.

Sölvsbergite.—The rocks belonging to this group are characterized by the presence of alkali-feldspar with aegirite or a soda-hornblende, with occasional biotite and very little or no quartz. In Norway the structure is generally trachytic, which is not the case in Essex county, but the similarity otherwise, both mineralogically and chemically, is so great that this structural difference may be overlooked.

The Essex county sölvsbergites are fine-grained and compact, not very porphyritic, and of a gray or blue-gray color. As the various dikes show rather diverse characters, they may be described separately.

One of these, from Dike 184, at Andrew's Point, Cape Ann, has already been described[1] as composed essentially of feldspar and glaucophane-riebeckite, with very little quartz. At that time, however, only sections from the border of the dike were available. Since then I have studied sections from the center as well with interesting results. The borders of the four-foot dike are very fine-grained and compact and of blue-gray color. At the center the rock becomes coarser, but is still fine-grained, and is composed of small black specks in a light gray groundmass.

Examining the sections under the microscope, it is seen that in the borders the hornblende is nearly constantly glaucophane, yet, as we approach the center, there are found streaks in which a bright grass-green aegirite partly replaces it. At the center the grain is larger, and the feldspars tend to become automor-

[1] H. S. WASHINGTON, Am. Jour. Sci. (4), VI, p. 176, 1898.

phic, the development being thick tabular, and a radiated arrangement quite common. The dark blue hornblende is present here in larger grains, but less abundant, while the green pleochroic aegirite, showing the usual characters is fully as abundant as it, and in places more so. The aegirite does not occur in needles, but mostly in stout, irregular anhedra, and only occasionally in rough prisms. Small crystals of a yellow-brown, highly pleochroic biotite are also seen. There are also numerous small, slender needles of a bright yellow pleochroic mineral, often arranged in stellate groups. Their pleochroism varies with the depth of their color, the deepest showing a reddish-yellow parallel to the length, and a lighter greenish-yellow perpendicular to this, while the paler ones show scarcely any pleochroism. These are the same which were thought to be either apatite or rosenbuschite in the former description, but here their larger size and more intense coloration permits of a better examination, and it seems that they are to be referred to astrophyllite.

A sölvsbergite of a somewhat different type is that forming Shaler's Dike 182, near Pigeon Cove, on Cape Ann. The dike itself is three to four feet wide, with strike N. 73° W. At one place a tongue of granite about ten feet in length protrudes into the dike. In this tongue, as well as immediately outside for a distance of twenty feet along the dike and a foot from it, the granite has been squeezed, and a gneissoid structure developed, the foliations on the outside bending around towards the tongue and being parallel to its length within it. Examined in thin section, the quartz and feldspars of this gneissoid granite are seen to have been squeezed, crushed, cracked, and frequently drawn out into lenticular shapes, exactly as in many gneisses. It is remarkable that such a squeezing should have taken place over such an extremely limited area, the granite outside of the gneissoid portion and on the other side of the dike being absolutely normal in character.

But to return to the dike. This is dark gray and compact, with a few small phenocrysts of aegirite and feldspar. In thin section, it is seen to be composed of a pale greenish hornblende,

pleochroic in light tints of blue-green and yellow-green, a with an extinction angle of 15°, partly in large, stout phen crysts, but mostly as small, irregular grains, with small, stc flakes of a peculiar light brownish-gray biotite, embedded microperthitic feldspar, generally in anhedra, but occasiona showing roughly tabular forms. Neither aegirite nor the n mal blue hornblende is to be seen, nor was any quartz found.

A very pretty sölvsbergite forms Dike 55, which cuts t granite at the pier of the Hawthorne Inn, East Gloucester. T rock is aphanitic and chiefly a dull gray, but is mottled w streaks of white or greenish-gray, which run parallel to the wa Under the microscope the only phenocrysts visible are a f sharply automorphic ones of alkali-feldspar, which are compos of orthoclase and albite, not arranged microperthitically, l forming aggregates of small granular anhedra. This structı seems to be due to secondary processes, as the rock is not qu fresh, and the sharp crystal outlines of the aggregates show tl they were originally well-defined crystals. The groundmass composed of a finely granular alkali-feldspar, possibly with little quartz, thickly sprinkled with small blue or green needl Most of these are of bluish-gray glaucophane, and are of t sizes. The smallest, usually less than .01 mm in length, tend accumulate in rounded patches or streaks, surrounded by clea feldspar carrying sparsely scattered, larger needles. Otl streaks occur in the sections, corresponding to the pale stre seen in the hand specimen, which are of feldspar carrying p green aegirite needles and grains, with little, if any, glaucopha In one place the orthoclase and albite are intergrown radial forming sphaerocrystals which give a black cross between cros nicols.

Another sölvsbergite, the specimen of which I owe to kindness of Mr. Sears, occurs as a dike at West Cove, Coı Island, in Salem Harbor. This has been described by Ros busch, who calls it a bostonite-porphyry.[1] To a certain ext

[1] ROSENBUSCH, Mikr. Phys., Vol. II, p. 425; also Elemente der Gesteinslehre, ı p. 198, where it is called "bostonitic alkali-syenite-porphyry."

y specimen agrees with his descriptions, especially as to the egascopical appearance, the feldspars and the flow structure. ut there is a marked discrepancy in the colored components, nd it is evident that here also the dike varies in character in ifferent parts, assuming that the two specimens came from the me dike. From analogy with the Andrew's Point dike, it ould seem that Rosenbusch's specimen came from the border, hile mine came from near the center.

The rock is rather dark gray, fine-grained, and, in my specien, with little suggestion of silky luster. The tabular alkali-ldspar phenocrysts are identical with those described by osenbusch. This author speaks of a blue glaucophane-like ornblende as the only colored component. In my specimen is occurs very sparingly, its place being taken by a highly leochroic, peculiar olive-green hornblende, bright green aegite grains, and flakes of a greenish-brown, intensely pleochroic iotite. Generally these are scattered uniformly through the ection, but in places one or the other predominates. A few henocrysts of colorless diopside are seen, surrounded by a narow border of aegirite. A number of fair-sized titanite grains nd a few apatite needles are present, but quartz is wanting. low-structure is very pronounced, and is well brought out etween crossed nicols, on account of the highly tabular development of the groundmass feldspars.

The last of the sölvsbergites to be described was found as blocks in a wall along the back road southwest of Bass Rocks. It is very dense and compact and of a deep bluish-gray color. Under the microscope no phenocrysts are visible, and practically the only colored component is a deep blue glaucophane, which occurs in abundant needles or stout prisms. There are also present, in extremely small amount, small grains of colorless diopside, but no aegirite, biotite, or green hornblende. The rock is chiefly remarkable for its colorless base, which is composed of alkali-feldspar, with considerable quartz—enough to justify the name quartz-sölvsbergite. These are partly irregularly granular, but also form small patches with micro-

graphic texture, which are highly characteristic and very abundant.

The provenance of these blocks is not known, but they probably come from a dike in the immediate vicinity. Search revealed an outcrop of a dense, very pale gray dike, with only a slight tinge of blue, near a small pond across the road. This is evidently a bleached-out sölvsbergite, since the microscope reveals the fact that the small, originally blue, hornblendes are nearly all entirely decomposed to an opaque black substance, with little change of form, and small crystals of diopside are also possibly derived from them. This rock also shows the peculiar and striking micrographic patches, and it is therefore highly probable that the wall blocks were obtained from freshly blasted portions of this dike.

Only two analyses have been made by me of these rocks, which are given below. For comparison there are quoted an analysis of the Coney Island dike recently published by Rosenbusch, as well as two analyses of Norwegian sölvsbergites.

	I	II	III	IV	V
SiO_2	64.28	61.05	60.60	62.70	64.92
TiO_2	0.50	0.34	0.71	0.92	....
Al_2O_3	15.97	18.81	18.28	16.40	16.30
Fe_2O_3	2.91	2.02	2.85	3.34	3.62
FeO	3.18	3.06	2.67	2.35	0.84
MnO	trace	trace	....	trace	0.40
MgO	0.03	0.42	0.52	0.79	0.22
CaO	0.85	1.30	0.99	0.95	1.20
BaO	none	none	....	....	....
Na_2O	7.28	6.56	6.66	7.13	6.62
K_2O	5.07	6.02	5.73	5.25	4.98
H_2O (Ignit.)	0.20	0.78	0.69	0.70	0.50
P_2O_5	0.08	....	0.15	....	....
	100.33	100.04	99.85	100.53	99.60

I. Sölvsbergite. Dike 184, Andrew's Point, Cape Ann. H. S. Washington anal. Amer. Jour. Sci., (4) VI, p. 178, 1898.

II. Sölvsbergite. Dike. Coney Island, Salem Harbor. H. S. Washington anal.

III. Sölvsbergite ("Bostonitic Alkali-syenite-Porphyry"). Coney Island. M. Dittrich anal. Rosenbusch, Elem. d. Gest. lehre., 1898, p. 199, No. 3.

IV. Katoforite-Sölvsbergite. Lougenthal, Norway. L. Schmelck anal. Brögger, *op. cit.*, I, p. 80.

V. Aegirite-Sölvsbergite. Sölvsberget, Gran, Norway. L. Schmelck anal. Brögger, *op. cit.*, p. 78.

The Andrew's Point sölvsbergite is rather acid and approaches osely the katoforite-sölvsbergite from the Lougenthal. It sembles the Coney Island dike in its main features, especially the high alkalies and the relations of the iron oxides. The o analyses of the Coney Island dike resemble each other very tisfactorily, and show that it is rather more basic, approaching e Kjöse-Aklungen dike, which, however contains a little nephe-e. It is evident from these analyses and the descriptions ven that the Coney Island rock is really a sölvsbergite and not bostonite-porphyry, for which indeed, as Rosenbusch himself marks, it carries an abnormally large amount of colored min-als.

Tinguaite.— The most basic members of the series we are ow discussing, the tinguaites, which are not abundant in Norway, ccur very sparingly in Essex county, only three dikes of this ck having come to my notice.

One of them, an analcite-tinguaite, from Pickard's Point near lanchester, has been already described.[1] It is aphanitic and live-green, with only rare phenocrysts of feldspar in a ground-ass of aegirite needles, alkali-feldspar, nepheline and analcite. he perfect freshness of the rock, as well as theoretical consid-rations, lead to the conclusion that the analcite is primary.

The second tinguaite occurrence is that recently described by Dr. A. S. Eakle[2] as a biotite-tinguaite from Gale's Point near lanchester. It is composed of alkali-feldspar, nepheline, kao-in and secondary quartz, aegirite, and a little biotite and mag-etite. As Dr. Eakle points out it approaches the nepheline-earing sölvsbergite from Kjöse-Aklungen already mentioned, nd might be classed with the sölvsbergites.

The third occurrence of tinguaite is a dike two hundred yards ast of Squam Light, discovered by Mr. Sears, to whom I am idebted for a specimen, The rock is dark green and very ense. This is also a biotite-tinguaite and very fresh. No henocrysts are visible. Abundant small irregular grains and

[1] H. S. Washington, Am. Jour. Sci., (4), VI, p. 182, 1898.

[2] A. S. Eakle, Am. Jour. Sci., (4), VI, p. 489, 1898.

prismatic crystals of aegirite with fewer small flakes of br biotite, are strewn in a colorless base composed of small tab alkali-feldspars with interstitial nepheline. Colorless needle what is probably diopside are also present, but no magnetite seen. The rock shows a well marked flow structure.

Of these rocks we have two analyses, both already publis one of the Pickard's Point analcite-tinguaite, the other of biotite-tinguaite. With them are given for comparison anal of the border and center of the Hedrum tinguaite dike and Kjöse-Aklungen sölvsbergite.

	I	II	III	IV	V	
SiO_2	56.75	60.05	56.58	55.65	58.90	!
TiO_2	0.30	0.11	....	....	0.40	
Al_2O_3	20.69	19.97	19.89	20.06	17.70	:
Fe_2O_3	3.52	4.32	3.18	3.45	3.94	
FeO	0.59	1.04	0.56	1.25	2.37	
MnO	trace	0.79	0.47	....	0.55	
MgO	0.11	0.23	0.13	0.78	0.54	
CaO	0.37	0.91	1.10	1.45	1.05	
BaO	none	....	....	....	....	
Na_2O	11.45	7.69	10.72	8.99	7.39	
K_2O	2.90	3.24	5.43	6.07	5.59	
H_2O (110°)	0.04	0.15	....	....	....	
H_2O (ignit)	3.18	1.26	1.77	1.51	1.90	
Cl	0.28	0.28	....	....	....	P_2O_5
	99.92	100.04	99.83	99.21	100.33	(

I. Analcite-Tinguaite, Pickard's Point. H. S. Washington anal. Trace of Am. Jour. Sci. (4), VI, p. 185, 1898.

II. Biotite-Tinguaite, Gales Point. A. S. Eakle anal. Am. Jour. Sci. (4 p. 491, 1898.

III. Tinguaite (dike border). Hedrum, Norway. G. Pajkull anal. Brö *op. cit.*, I, p. 113.

IV. Tinguaite (dike center). Hedrum. V. Schmelck anal. Brögger, *op* p. 191.

V. Nepheline-Sölvsbergite. Kjöse Aklungen, Norway. V. Schmelck Trace of P_2O_5. Brögger, *op. cit.*, p. 102.

VI. "Phonolite" (Tinguaite ?) H. N. Stokes anal. Southboro, Mass. Bull U. S. G. S., p. 77.

In I the only points which need be mentioned here the rather low silica, high soda, and, for so fresh a rock, the

content of water. It very closely resembles the Hedrum border rock, except in water and potash. The biotite-tinguaite is more acid, and closely corresponds in general features to the analysis of the Coney Island sölvsbergite. The characteristic distinction, however, is found in the relative amounts of the iron oxides and in the alkalies. In these respects the two tinguaite analyses resemble each other, and these two features, taken together, serve to differentiate their analyses from those of the more basic sölvsbergites. This whole series presents several points of interest, as regards the relations of the various members to each other, and their relative composition, but discussion of these features will be deferred to a later page. In connection with these rocks I may call attention to a so-called phonolite from Southboro, Mass., whose analysis is given in VI. Although not described an examination of sections of specimens kindly sent me by Professor B. K. Emerson proves that they are typical aegirite-tinguaites, one specimen showing very sharp nepheline crystals.

HENRY S. WASHINGTON.

(To be Continued)

THE DISTRIBUTION OF LOESS FOSSILS

It has perhaps been noted that the loess molluscs thus far reported in the literature of the subject are, for the most part, from localities in close proximity to the larger streams. This fact may have suggested the thought to those unfamiliar with the modern habits and present distribution of these molluscs that the adjacent streams had in some way something to do with the entombing of the shells now found in the loess. That the loess is most richly fossiliferous near streams is generally, though not always, true. The abundance of fossils is a decidedly variable quantity. There are exposures near streams which exhibit fossils in profusion, and others which are wholly barren. On the other hand, exposures quite remote from streams contain fossils —though in such situations a proportionately much larger part of the loess is entirely devoid of them.

This fact has sometimes led geologists to attempt to distinguish, in varying degrees, between the loess adjacent to streams and loess more remote. Whatsoever distinction may be observed in the physical characters of the loess of various deposits,[1] no distinction can be based on the presence or absence of fossils alone. The simple fact that one deposit is fossiliferous and another is not, does not prove, nor even indicate, that the deposits were formed under wholly, or even materially different circumstances. In the one case there are no fossils simply because there were no shells to be buried; in the other, fossils are common because shells were abundant on the old land surfaces, where they were covered as other imperishable objects would have been covered.

Fossils are more abundant in the vicinity of streams because

[1] For one of the most recent discussions of the loess with reference to its variation according to distance from streams, see Dr. Chamberlin's article in the JOUR. GEOL., Vol. V, No. 8, p. 795.

the same species thrive, and in all probability did thrive in the past, in just such situations.

Manifestly, if we would judge of the conditions under which the fossils existed and were finally buried in the past, we must understand the conditions under which the same species exist today. It has already been pointed out by the writer[1] that the loess fauna of any section of the country closely resembles the modern molluscan fauna of the same section, the characteristic fossil species being for the most part characteristic species of the modern fauna. During the past summer the writer made more extended studies of fossils in widely separated loess regions, notably in Mississippi, Iowa (both eastern and western), and Nebraska, which strongly emphasize the foregoing fact. As questions of general geographical, as well as local, distribution of fossil and modern molluscs are of great importance in connection with any attempt at an explanation of the manner in which loess was deposited, the following remarks are offered as preliminary to further detailed reports upon the distribution of the loess species and of their modern representatives.

In Iowa and Nebraska, as elsewhere, the land shells form the characteristic fauna of the loess, and with two or three exceptions the same species may be found living within the borders of our state today.

The student who goes to the field to study the living forms in their natural environment, if his studies be sufficiently extended, will be struck by the many seeming eccentricities in distribution. He will, however, observe that our land molluscs as a rule favor the regions adjacent to streams — especially the rough, rugged hills which so often border them. This fact, however, seems to be dependent upon another, equally interesting and long well known — namely, that our timber areas for the most part skirt the streams — and that this distribution of vegetation determines largely the distribution of the molluscs is shown by the fact that the timber or brush-covered areas remote from streams are quite likely to yield plenty of shells. A few

[1] Proc. Iowa Acad. of Sciences, Vol. V, pp. 33, 41.

species (as for example *Succinea grosvenorii*) seem to favor open, rather grassy places, and a few others may be found among the weeds and bushes skirting prairie ponds, but as a rule rough, rolling timber areas are favored. Here an abundance of food (for nearly all are herbiverous) and more or less shade and protection are furnished by the vegetation. As we recede from the timber-bordered streams the number of species and specimens grows less, and the writer knows from personal experience obtained in various parts of the state that large prairie areas of that character may be searched in vain for any trace of a land mollusc. In the eastern part of the state, with its more rolling, timber-covered surface, almost every locality—certainly every county—presents numerous favorable locations for colonies of snails, but as the collector crosses the state westward he finds that in species and in specimens the molluscan fauna grows poorer, the timber-fringed streams or ponds and lakes alone marking the favorable localities.

If careful observations are made even in the best of these collecting grounds, whether in the eastern or western parts of the state, it will be found that much variation and inequality in local distribution exist. One hillside may present certain species, while the next, perhaps across a narrow ravine, will show a wholly different series, and a third near by may have none at all. A species which in one spot is the prevailing type, may, only a few rods or even feet away, be wholly or in part supplanted by another. This is sometimes due to differences in the abundance of trees and vegetation furnishing food, and to other variations in the character of the surface, but often it seems to be a mere accident.

The number of individuals of any, or all, species in a given locality is also very variable. In the most favorable spots, however, especially on higher grounds, one seldom finds many individuals together. Even such species as *Zonitoides arboreus*, *Z. minusculus*, *Vitrea hammonis*, *Cochlicopa lubrica*, *Succinea obliqua*, *S. avara*, etc., which may often be found in large numbers under leaves or sticks and logs in comparatively low places, usually show

fewer and more scattered specimens on hillsides, etc., especially in more open places. To get a good set of any species in such localities the collector must work over a considerable area, but in doing so he will almost invariably find individuals of several species mingled promiscuously. If he compares the molluscan faunas of the eastern and western parts of the state, he will find that, as stated, the number of species and individuals in the eastern part is, as a rule, greater. He will also find that there are certain rather striking differences between sets of some of the species taken at opposite extremities of the state. Those from the eastern part are likely to average larger in size and to be thinner shelled, resembling more nearly representatives from the eastern part of the country, while the western forms are smaller and heavier. This is especially true of *Polygyra mutilineata*, *Zonitoides minusculus*, *Succinea obliqua*, *S. avara*, and other species of the kind which are sometimes found in rather low places, but which also occur on higher grounds—especially westward. This is probably due chiefly to the scarcity of forests in the western and central parts of the state, where the rather scant groves usually consist of scattered and stunted trees, being quite different from the more vigorous forests of the eastern part. That this view is correct is further attested by the fact that the same species of molluscs, when occurring on comparatively barren or nearly treeless areas in the eastern part of the state, usually show the characters of the western types, namely, the smaller size and sometimes heavier, or at least more compact shell.

If the student will study the molluscs of a given region for a number of years, he will find that from year to year the abundance of the several species varies, some even running out entirely, while others unexpectedly appear. The writer has watched a number of localities near Iowa City for many years, and has found this variation often striking.

If, now, the distribution of the fossils in our loess is compared with that of the modern shells, a remarkable similarity is evident. The best collecting grounds are near streams, while the clay of the remote prairie is usually barren. Where fossils

are abundant one exposure contains species of one kind, another near by presents a new, or at least a different list, while still another has none—and the same variation which may be observed in the local distribution of the recent shells in any restricted locality, will be exhibited in individual exposures of fossiliferous loess.

In horizontal distribution the fossils show the same mode of distribution as that already noted in the modern forms. The specimens are not heaped together, but are scattered about like the modern shells, usually a number of species mingled together, but in unmodified loess invariably *not* crowded, so far as the writer's observations have gone.

The vertical distribution of the fossils also conforms to the surface distribution of the modern shells. If the loess was not deposited *in toto* at once, and this seems to be conceded, there were successive land surfaces upon portions of which shells grew. These shells varied from time to time in number, some persisted during long periods, some disappeared and others took their places. If we study the vertical distribution of the fossils in the loess the same variation in the succession of species is observed. Some species occur throughout the thickness of a particular exposure, but more frequently a part of the loess is without fossils, certain species occupy a part of the deposit, while above or below them are other species—as though the varying generations of surface species had been successively buried in the deposit. The number of specimens upon any one of the successive land surfaces was not very great even in richly fossiliferous loess, for if we draw lines approximately parallel to the present surface to represent the successive surfaces, we will find that in any one of them but few fossils occur.

Where depauperation or variation in size is noticeable in the fossils, it will be found that it takes place in the direction of the western modern forms. For example, while the common modern *Polygyra multilineata* at Iowa City is large, the common fossil form is small, though the small modern and the large fossil forms are also occasionally found, but not respectively with the

preceding forms. On the other hand, at Council Bluffs and Omaha the modern shells of this species are usually small, like those of the loess, though both fossil and modern shells of the large type occasionally occur. Thus the fossils of this species from the eastern part of the state resemble both the fossil and modern shells from the western part. *Succinea avara* is another example. The small typical form is common in the loess at Iowa City, but the modern shells are not frequent, occurring always on more or less wooded hillsides, while westward the type is the common modern form.

In the loess of both the east and the west,[1] *Sphyradium edentulum alticola*, *Pyramidula strigosa iowensis*,[2] *Succinea grosvenorii*, forms belonging now to the dry western plains, are quite common. Their presence, together with that of the "depauperate" forms, when considered in connection with the entire molluscan faunas of the eastern and western parts of the state, suggests a climate considerably drier than that of the eastern part of the state, and a surface less abundantly timbered. Certainly both modern and fossil faunas unmistakably show[3] that the conditions in the eastern and western parts of Iowa during the deposition of the loess were approximately included within the bounds of the present extremes presented by these regions, and that any attempt to drag into the discussion of this subject conditions either of a glacial climate or of frequent and widespread floods and inundations, or of any excess of moisture, is gratuitous.

The conditions which cause the depauperation of our shells exist more or less all over Iowa today, especially westward, and yet we do not have a glacial climate. If the molluscs

[1] The loess herein designated as "eastern" is that of eastern Iowa — the "western" being that of western Iowa and eastern Nebraska.

[2] This form has heretofore been reported as var. *cooperi* which lives abundantly in the far West, but Pilsbry regarded it as extinct and distinct, and has described it under the name *iowensis*. All living forms of *strigosa* belong to the high, dry regions of the West. Neither of these species was found at Council Bluffs, but both are found in the loess of Nebraska. *Sphyradium* was formerly included in *Pupa*.

[3] See also the writer's paper in Proc. Ia. Acad. Sci., Vol. V. — particularly p. 42.

of the loess be used as an absolute measure of the amount of moisture occurring during loess times, then we must conclude that Iowa was without streams, for practically no fluviatile molluscs occur in the loess, and that there were but few ponds in which aquatic molluscs found a favorable habitat, for even aquatic Pulmonates are rare in the loess,[1] the number of terrestrial forms being out of all proportion to that of the aquatic forms.

During the past summer the writer collected several thousand specimens in the loess of Mississippi and western Iowa, and among them all there were not a half dozen aquatic shells. A list of the modern shells of Iowa shows a large number of aquatic species, yet few of these occur in the loess. There is also among the modern terrestrial forms a large number of those which occur only in very damp places—and these, too, are almost wholly missing from the loess. The writer is well aware that many of the forms found in the loess are often referred to as aquatic or "semi-aquatic," or at least as favoring very wet situations. But evidence of this character has been furnished largely by those who are familiar only with the molluscan fauna of the eastern part of the country, where the amount of rainfall is much greater, and where surface conditions are not the same as in Iowa and Nebraska—or it has come from so-called "closet-naturalists." Now, the "closet-naturalist" has done abundant harm in this as in other branches of science. Too remote, often, from the phenomena under discussion, or too dainty to soil his fingers with the toil and the exposure of field-work, he has passed judgment upon the habits of forms which he knew only from material submitted by mail—or still worse, he has taken the work of others and, not appreciating the significance of the facts so borrowed, has distorted them to do menial service in the encouragement of some pet notion.

In the particular case in hand no distinction has been made between the habits of the depauperate varieties and the larger

[1] For more detailed comparisons see writer's paper (*loc. cit.*, pp. 43 and 44), and the discussion preceding.

types of the same species, and too often the habits of one species have been confused with those of another of the same genus, or even family, a mistake most frequently made with the Succineas. Again, the versatility of certain species—their adaptability to varying conditions—has been overlooked. *Zonitoides minusculus*, *Bifidaria pentodon*, *B. contracta*, *Succineaavara*, *S. obliqua*, etc., frequently occur in low places and then often in great numbers—but they are also found scattered over comparatively dry hillsides at considerable altitudes—and some of these species in such places develop the depauperate type, that is they average smaller in size. To show the preponderance of strictly terrestrial forms in the loess, the writer calls attention to the fact that in the collections made last June at Natchez and Vicksburg, Miss., numbering over forty species and nearly five thousand specimens, there is not a single aquatic form. Furthermore, every species which was collected in the loess of that region has been found by the writer, living upon the high bluffs and hills in and near Natchez, or upon hillsides at considerable elevations in other parts of the south, notably in northern Alabama, Georgia, and Tennessee.[1] At Natchez the most common living species is *Succinea grosvenorii*, and this crept upon the bare surface of the loess clay which, at the time of the writer's visit, had been baked by the hot summer sun of the south during a period of drouth lasting more than six weeks. Moreover, several scores of specimens which had been carried about in the sun all day long in a box containing loess dust, and hence were subjected to extremely desiccating conditions, were found, after this experience, creeping about in their prison seemingly perfectly contented. Yet we are sometimes told that the Succineas are all "semi-aquatic," or that they must have an abundance of moisture. Another illustration, equally striking, is furnished by the writer's experiences and observations at Council

[1] It is also a significant fact that of all the living species found in the hills and bluffs of Natchez, only two, *Leucocheila fallax*, and *Polygyra texana*, were not found in the loess of that region. Only one specimen of the first and two of the second were collected. The former is not uncommon in the loess of the north, while the latter is not known from the loess, at least to the writer.

Bluffs during the past summer and autumn. It had been purposed to make a detailed comparative study of the fossil and modern molluscan faunas of that vicinity, but the work was somewhat interrupted by the severe September rainstorms and November blizzards. Nevertheless interesting and valuable data were obtained, and are here briefly presented.

More than four thousand fossils were collected, and their distribution was carefully noted in twenty exposures, beginning at the eastern extremity of 15th avenue in Council Bluffs, thence along the bluffs to the High School, a distance of about one mile and in Fairmount Park, along its winding roads, for about half a mile eastward. The location of the several exposures is shown on the accompanying map. A list of the fossil species, together with the number of specimens collected in each exposure, is given in the appended table. If this table is studied it will be observed that of the thirty species collected not one is aquatic. For purposes of comparison the writer made collections of recent shells in seven distinct localities in practically the region containing the above-noted exposures. These localities are here discussed in detail, the letters designating them being also employed to mark them on the map.

a. A grassy, treeless hillside in Fairmount Park nearly opposite 11th avenue, and at an altitude of from 175 to 245 feet above the river valley.[1] Species 8, 11, and 29[2] were found living.

b. A grassy, treeless slope just above the exposure marked *N.* Altitude about 200 feet. Species 8, 10, 11, 15, and 29 were found.

c. Near the 10th avenue entrance to Fairmount Park, at an altitude of about 90 feet above the river plain, species 8, 10, 1 21, 22, 27, and 30 were found. A few stunted and scattered bur oaks grow on the slope immediately above this point.

d. A brush-covered hill just above the exposure marked *L*

[1] The altitudes were all determined by barometric measurements taken from the nearest north and south street on the river flat.

[2] The numbers refer to the species named in the table of fossils.

Altitude about 170 feet. A small collection containing species 11 and 30 was made.

e. A locality in the northwestern part of Fairmount Park on a northerly slope, somewhat grassy, but with shrubs and a few bur oaks, nearly opposite 8th avenue. Altitude 280 to 300 feet above the valley. Here were found species 3, 8, 11, 13, 18, 19, and 27, and also one specimen of *Bifidaria procera*, the only recent species found in the tract examined, which was not found in the loess. This locality is just over the brow, on the north or leeward side,[1] of one of the most exposed ridges in the area under consideration.

f. A part of the same slope immediately below *e*, and 50 to 100 feet lower. Here the forest is better developed and contains a number of species of trees. Species 8, 11, 18, 19, 22, 25, and 28 were found. The points *e* and *f* are on the same very steep slope, but *e* is much more exposed and drier, *f* being more proteeted by its forest covering and position. A comparison of the species from these points is therefore interesting. Species 3 and 13, while common at *e* were not found at *f*, the lower point. While 18 was common at *e*, only one specimen was found at *f*. No. 19 is also more common at *e* than at *f*. These facts are of interest when we seek to determine the extent to which shells are likely to be washed down even very steep slopes. Nos. 8 and 11 were about equally abundant, while Nos. 22, 25, and 28 were found only at *f*.

g. The banks and grassy slope near and above the exposure *M*. This yielded species 3, 13, 21, 24, and 27.

It will be observed that species 1, 2, 4, 5, 6, 7, 9, 12, 14, 15, 16, 17, 20, 23, and 26—or just one half the total number—are not contained in the collections of modern shells cited. The number of individuals of the surface species is also comparatively small. Of these numbers, 1, 16, and 23 are extinct in that section of the country, No. 1 occurring eastward, No. 16 westward, and No. 23 being entirely extinct.

[1] The prevailing winds during the seasons of the year when the snails are active, are from the southwest.

The modern fauna of the more or less exposed hills at cil Bluffs is much poorer in species and in specimens tha fossil fauna of the underlying loess, but every species th discovered in the loess of Council Bluffs occurs more c abundantly (certainly as abundantly in some places as i part of that loess) living along the Missouri River, especia the western, more heavily timbered bluffs. All the s above mentioned as not found in the surface collections been collected, by the writer, on the banks and hills alor Missouri between Omaha, Neb., and Hamburg, Iowa, u not in very damp places, but living under the conditions prevail along those bluffs. Even *Polygyra multilineata* is often found on high grounds, and then appears as a st form like that which is common in the loess.

The loess fauna of Council Bluffs is thus not only v terrestrial, but, with the exceptions noted, is almost ide with the modern upland fauna of the same region — and no conditions of excessive moisture prevail in that region Yet a recent writer,[1] referring to the loess of the Missouri r says: "In the Bluff loess more than nine tenths of the number of individuals belong to species that are found c unusually damp situations. . . . . The species having ar mum habitat that is not excessively moist have not observed to occur abundantly in the Bluff loess."

Another interesting fact noticeable in the exposures ol at Council Bluffs is the occurrence of the great majority fossils in a more or less distinct stratum which varies (so observed) in altitude from about 80 to at least 200 feet the river valley, and which follows in general the conte the present surface, but with a less convex curvature exposure *N* it seems to be a continuation of the shell-b layer in *E*, yet it is at least 100 feet higher. In exposure drops about 80 feet in a block. Its limits are not s defined above or below, and it varies in thickness from 6 to at least 20 feet. Overlying it is a deposit of more c

[1] C. R. KEYES, Am. Jour. of Science, Vol. VI, p. 304.

laminated loess clay, which is usually non-fossiliferous, and which varies from a few to more than 30 feet in thickness. When fossils occur in this upper stratum they are few in number and widely scattered.[1]

The presence of this shell-bearing stratum suggests that, for the period during which it formed the surface soil, and while it was slowly accumulating, the conditions in this particular locality were more favorable to the growth of land snails than now. There was probably more vegetation, and hence the surface was not so frequently storm-swept as at present. This does not necessarily signify that general climatic conditions were different, but that these particular banks or bluffs were more heavily timbered, with the Missouri River probably flowing at its base, its surface conditions being similar to those of many timbered hills and knolls between Omaha and Nebraska City west of the Missouri.

It is interesting to note that between Iowa and Nebraska the Missouri River now flows along the western side of its broad valley, and that the adjacent western bluffs are more heavily timbered and contain all the living species of molluscs herein recorded, with the exception of Nos. 1 and 16, while the more remote eastern bluffs are more barren and rugged. The shell-bearing band may simply represent the period during which the river in its shiftings occupied the eastern part of the valley.

The foregoing facts lend support to the æolian theory of the origin of the loess, as is shown by the following considerations.

1. The general manner of distribution of the modern and fossil molluscs is essentially the same, this fact indicating that they were not carried by waters, but were quietly buried in dust. Had they formed a part of river drift they would be more frequently heaped together, not scattered as we find them in the loess, and fluviatile shells would be more or less intermingled.

[1] At the base of the bluff, in exposure *K*, what seemed to be a second shell-bearing layer was observed about 75 feet below the main fossiliferous band. The section, however, was more or less obscured, and the mass may have slipped from the bluff above. The fossils in column *K* in the table are from this stratum. It will be observed that they are ordinary forms which are abundant in the main shell stratum.

Moreover in many years' experience in dredging in ponds and streams, the writer has seldom seen a land shell which had been carried with the finest sediment into ponds or lakes, though such shells are sometimes found in sand and other coarse material. Currents of water which could carry most of the shells now found fossil, would also carry coarser material than that which makes up the loess. Another fact which bears out this conclusion is the presence of opercula in fossil shells of *Helicina occulta* in the northern loess and *Helicina orbiculta* in the southern loess. As the operculum so readily falls from the decaying animal, it would scarcely remain in place if the shell had been transported any distance.

2. The occurrence of fossiliferous loess chiefly in the vicinity of streams is consistent with the theory of loess formation presented by the writer before the Iowa Academy of Science.[1] Plants, and especially forests, develop chiefly and primarily along streams. This creates conditions favorable to land molluscs, and at the same time forms a trap for the dust carried from adjacent more barren regions. The occurrence of loess in the eastern part of Iowa chiefly along the border of the Iowan drift sheet may also be explained on the same ground. After the melting of the ice the terminal moraines offered the first lodging place for plants. Here forests early developed, and the conditions for entrapping the dust from adjacent less favored territory which was probably dry during a part of the year were here first created. We are in the habit of describing the lobed ridges of loess regions as characteristic of loess topography, yet they are quite as much characteristic of some drift areas, as for example, along the Big Sioux River in Iowa and South Dakota. In eastern Iowa the surface of the loess is largely shaped by the underlying moraines which first presented conditions suitable to the deposition of the loess, and where consequently the deposit is best developed. The loess at Natchez does not show this loess topography in the same degree.

3. The depauperation of some forms of shells, and the pres-

[1] Proc. Iowa Acad. Sci., Vol. III, p. 82 *et seq.*

ence of others which are normally inhabitants of dry regions, suggest a climate sufficiently dry that during a part of the year at least, clouds of dust could be taken up by the winds.

4. The overwhelming preponderance of land snails in the loess must always be borne in mind. This however does not prove that the loess regions were entirely devoid of lakes and streams, but rather that the loess proper was deposited chiefly upon higher grounds, for, if by any agency fine material were to be uniformly deposited over all of Iowa today, covering the successive generations of our present molluscan fauna, there would be a much greater proportion of aquatic and moisture-loving species than we find anywhere in the loess.

5. The amount of material carried by the winds need not have been so great as is sometimes assumed. The estimate made by the writer[1] for the rate of deposition for eastern loess (1 mm per year), and that made by Keyes[2] for western loess ($\frac{1}{16}$ to $\frac{1}{4}$ of an inch), would be sufficient to form most of these deposits respectively in the 8000 years, usually computed, since the recession of the glaciers.

The objection made by Dr. Chamberlin[3] that "the æolian deposits are measured, not by the quantity of silt borne by the winds and lodged on the surface, but by the difference between such lodgment and the erosion of the surface," is met, at least in part, by the theory offered, for it is a well-known fact that timbered areas, even when very rough and with abrupt slopes, are scarcely eroded by even the most violent precipitation of moisture. Professor Udden's recent admirable report[4] also bears on this question, and should not be overlooked by the student of loess problems.

6. No distinction can be made between the origin of eastern and western loess. The finer quality and lesser thickness of the former rather suggest that there had been more moisture (*i. e.*,

[1] Proc. Iowa Acad. Sci., Vol. III, p. 88.

[2] Am. Jour. of Sci., Vol. VI, pp. 301, 302.

[3] JOUR. GEOL., Vol. V, p. 801.

[4] The Mechanical Composition of Wind Deposits, 1898.

a shorter dry period during each year), and hence less dı that the winds were less violent, and that there were gre: areas completely covered with vegetation, this resulting in necessity of transporting dust much greater distances, wh would therefore be finer.[1]

It should be borne in mind that the above-noted differen between the regions in question actually exist today. There more rain, there are larger areas closely covered with vegetati and less violent winds prevail, in eastern Iowa, and eastward, a considering the position of mountain chains and seas, the sa differences must have existed for a long time. That they exist during the deposition of the loess is also indicated by proportionately somewhat larger number of species in the east loess, which prefer or require moist habitats. But the fauna the eastern, or Mississippi River loess is essentially a terrest fauna. The great fluviatile groups now everywhere commor the streams of eastern Iowa are wanting in the loess, and the fossil aquatic species are such as today prefer ponds, and often found even in those which dry up during the summer.

It may again be emphasized that the fossils show no grea difference between the surface conditions which existed dur the deposition of the loess of the eastern and the western pa of Iowa, than exists today between the surface conditions of same regions. This fact is irrefutable, and must not be ov looked in any discussion of the conditions under which lo was deposited.

NOTES AND EXPLANATION OF MAP

[Scale, 8 in. to 1 mile]

The exposures are represented by heavy lines.

EXPOSURES *A*, *B*, and *C*

These were cut out of the same ridge in street grading. The shell-bea stratum shows well on the east, south and west sides of *C*. It is about 1: feet thick. Above it there is a layer of clay about fifty feet thick and alı entirely devoid of fossils.

[1] See UDDEN, *loc. cit.*, pp. 56, 57 and 67.

TABLE OF SPECIES[1]

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
1. *Helicina occulta* Say	5	55	210	5	5	81	17	89	9	14	3	12	14	96						
2. *Vallonia gracilicosta* Reinh.	10	157	12		1	8		21		3	1	1	1	45	1			1		
3. " *parvula* Sterki	2																		1	
4. " *perspectiva* Sterki	3	12																		
5. *Polygyra multilineata* (Say) Pils.		6	70	2		16	4	7		6	1		2	3	1		2		1	1
6. " *profunda*[2] (Say) Pils.																				
7. " *hirsuta*[3] (Say) Pils.	1																			
8. " *leai* (Ward) Pils.	4	21	63	1	1	17	2	14		4			1	12			2			
9. *Strobilops virgo* Pils.	8		3			2		1	1					1						
10. *Leucocheila fallax* (Say) Try.		2																		
11. *Bifidaria armifera* (Say) St.	35	280						3	1											
12. " *contracta* (Say) St.	5																			
13. " *holzingeri* (St.) St.								1												
14. " *curvidens* (Gld.) St.	1																			
15. " *pentodon* (Say) St.												2	4	12			2	3	2	
16. *Pupa blandi* (Morse) Binn.	11	127			1															
17. *Vertigo bollesiana* Morse												10	3	28						
18. *Cochlicopa lubrica* (Müll.) P. & J.	1	4	27	1	1	12		22	1	2				18						
19. *Vitrea hammonis* (Strom.) P. & J.	2	3	10			10	1	3			1	1		1						
20. " *indentata* (Say) P. & J.			1																	
21. *Conulus fulvus* (Drap.) Müll.						1		1	1				1	5						
22. *Zonitoides arboreus* (Say) St.	3	4	21			4	2	12						10			3			
23. " *shimekii*[4] (Pils.) P. & J.															2		1		2	
24. " *minusculus* (Binn.) P. & J.	1	2	6			1		3			1			7						
25. *Pyramidula alternata* (Say) Pils.		4	19		1	4	1	11	3	2				1						
26. " *striatella* (Anth.) Pils.	1	20	46	3		21		28	2		1	4	4	24	2			3	1	
27. *Helicodiscus lineatus* (Say) Morse	6	18	6		1	7		5						13						1
28. *Succinea obliqua*[5] Say } 29. " *grosvenorii* Lea }	3	180	935	8	10	235	58	279	8	72	21	12	5	250	4	2	15	3	15	3
30. " *avara* Say	15	11	16			7	1	11		2	1	3	2	14	4	2		3	5	
31. Egg of a land snail						1										1				

EXPOSURE *D*

The shell stratum is not so rich in fossils as in *C*. Above it there a 15–20 feet of clay in which a few Succineas were found. In the clay bel the shell stratum there are several distinct but irregular bands of lir nodules—some very large.

EXPOSURE *E*

Very similar to *D*, but with only one band of nodules.

EXPOSURE *F*

Fossils are very abundant in the shell stratum, which can here be trac for 3 or 4 rods. The shell-less loess above is 8 or 10 feet thick.

EXPOSURES *G*, *H*, *I*, *J*, and *K*

These exposures were all formed from the same ridge by deep cuttii and grading. The shell stratum is distinct in all of them, and, as in all t other sections, it follows in general the contour of the surface. It varies thickness here from 6 to 20 feet. It is by no means equally fossilifero throughout.

EXPOSURES *L* and *M*

These were formed by the grading of High School avenue. The stre slopes westward from the High School, and drops about 60 feet in a bloc

[1] The nomenclature of Pilsbry and Johnson's recent *Catalogue of the Land Shell North America* is here employed. As there are some departures from former usa the changes are here noted:

Species 2, 3, and 4 were formerly included under *V. pulchello.*

Species 5 and 6 were referred to the genus *Mesodon*, and 7 and 8 to *Stenotrema*

Species 9 was included under *Strobila labyrinthica.*

The species of *Leuchochila* and *Bifidaria* were included in *Pupa.*

Species 18 was called *Ferussacia subcylindrica.*

Vitrea, *Conulus*, and *Zonitoides* were formerly placed in the genus *Zonites*, No. 19 was called *Zonites radiatulus.*

Pyramidula was formerly *Patula.*

Species 29 was called *S. lineata.*

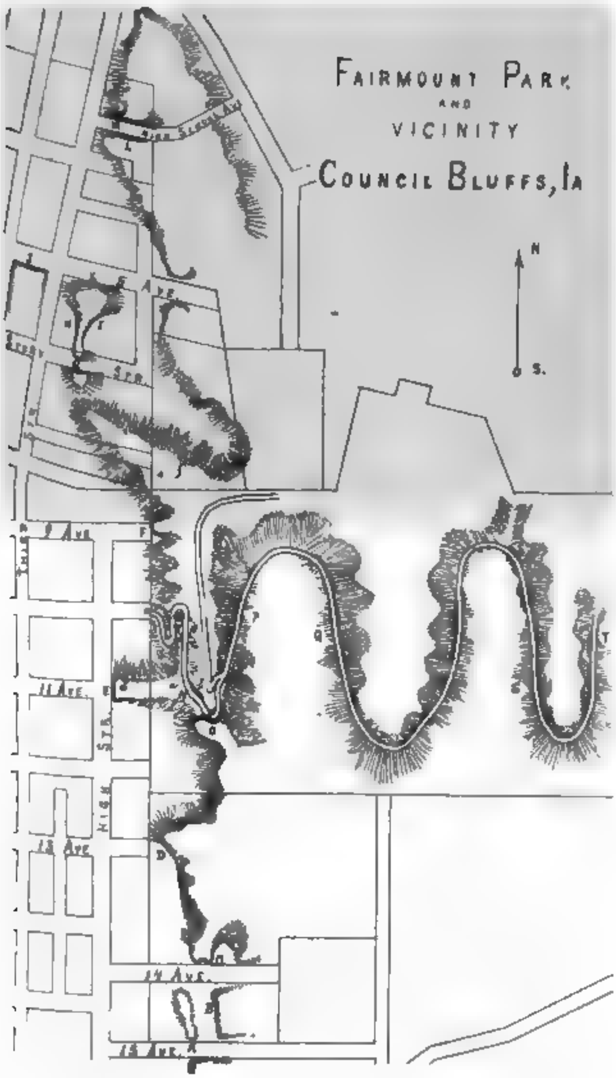
[2] One specimen of *P. profunda* was found by the writer in exposure C (since c siderably altered) in 1890.

[3] Three specimens of this species were collected in exposure C in 1890.

[4] The writer formerly regarded this as a form of *Zon. nitidus.* Mr. Pils however, regards it as distinct, and in deference to his opinion his name is retained

[5] The form of *S. obliqua* which occurs most commonly in the loess is the narrov smaller form, with more extended spire, such as is not uncommon (living) in Iowa a as far east as Indiana. As it is difficult to distinguish between some forms of this a *S. grosvenorii*, the two species are not here separated, as more time for careful cc parison of the large sets will be required.

On the north side the shell stratum is nearly parallel to the street grade, and but little above it. On the south side it dips below the street about half way down the slope.



EXPOSURES *N, O, P, Q, R, S,* and *T*

These are all exposures along the road which winds eastward from the 10th avenue entrance to Fairmount Park. At *N* the road is about 185

feet above the river valley, and the shell stratum (which is here very rich in fossils) extends about 3 feet higher. It dips down toward the west at such an angle that it would connect with the shell stratum at *E*, which is about 100 feet lower. The same layer may be traced more or less indistinctly to *O*, where there is a cut about 20 feet deep. The shell stratum rises to about 8 feet above the roadbed (here about 200 feet above the river valley), but fossils are not abundant. The remaining exposures along this road are formed by the road cutting the smaller, lateral lobes of the greater ridges. The letters apply to the extent of road from bend to bend not to individual exposures. At the southern bends in the road are the high points, the road sloping down to near the bases of the ridges to the north.

Fossils are found in most of the little exposures (which in but few cases exceed 15 feet in height) along the road, but they are nowhere as abundant as in some of the exposures along the bluff fronts. The exposures which are represented on the map, but not lettered, are nonfossiliferous.

B. SHIMEK.

THE GRANITIC ROCKS OF THE SIERRA NEVADA[1]

The higher part of the central Sierra Nevada and nearly the entire width of the southern Sierra consist of a granular complex to most of which the name granite is ordinarily applied. In the northern and central part of the range there are likewise numerous isolated granitic areas enclosed in rocks of other kinds. The rocks of the granular complex differ greatly in age and in chemical composition. The oldest rocks represented are gneisses. Some of these are probably recrystallized sediments, but the larger portion of them may be of igneous origin. While differing in origin these gneisses are a unit in that they have all undergone a thorough recrystallization under great pressure. While the associated granites may be in part responsible for this recrystallization it cannot be ascribed to contact metamorphism alone, for areas miles in diameter are as thoroughly crystalline in their middle portions as at the granitic contact. At a future time these gneisses will be described. Some notes regarding them may be found in the Seventeenth Annual Report of the United States Geological Survey and in the text of the Big Trees folio.

The granolites[2] of the Sierra Nevada comprise nearly the entire range of granular igneous rocks. Peridotite, pyroxenite, hornblendite, gabbro, diabase, diorite, syenite, monzonite, and granite, with various intermediate types, are all represented. In this paper, however, reference will be made only to the granitic

[1] Published by permission of the Director of the U. S. Geological Survey. A large amount of information has been accumulated about the granular complex of the Sierra Nevada. It is thought better, however, to delay the publication of this material until the field work now under way is completed. There is some confusion in regard to the biotite-granite of the range and the granodiorite and quartz-monzonite. They are, therefore, more fully treated than other types of which only a brief statement is presented here.

[2] The term granolite is here used for all granular igneous rocks; thus diorite, gabbro, syenite, and granite would all be called granolite. It was first suggested by Professor L. V. Pirsson.

rocks or acid granolites, those containing free silica or quart an essential constituent, that is to say, in considerable amo

Seven types of quartz-granolites have thus far been recogni The relative age of all of them is not definitely ascertained, so far as known it is expressed in the order in which the diffe types are enumerated, as follows: biotite-granite, granodio quartz-monzonite, porphyritic quartz-monzonite, Bridal granite, soda-granite and aplite, potash-aplite and pegmatite

BIOTITE-GRANITE

Biotite-granite forms very large areas in the central por of the Sierra Nevada. It is particularly abundant in the Trees and Yosemite quadrangles,[1] where it has been exam most closely. The coarse biotite-granite is a rock susceptibl easy recognition in the field. Potash-feldspar is an abun constituent, and by its conspicuous development in relati large crystals tends to give the rock a porphyritic look. O minerals less readily seen with the naked eye are quartz biotite; the former in distinct grains of irregular shape, the latter so arranged as to give a suggestion of gneissi banded texture, even in hand specimens. Perfectly fresh sp mens are secured with difficulty as the rock weathers to a siderable depth and becomes somewhat friable. Under microscope the porphyritic texture is generally inconspicu The component minerals are soda-lime-feldspar (oligoclas quartz > potash-feldspar > biotite > titanite > apatite > zir The relative proportions of these minerals are deduced fro calculation as noted later. Chlorite is usually present as a dec position product of the biotite, and secondary epidote may c be noted. Rutile-like needles were observed in some quar

Biotite-granite usually weathers in yellowish tones, an forms suggestive of bedding, due to a more or less well-de oped gneissic structure. Indeed, at many points the bio granite has been greatly compressed and sheared, so that n

[1] As used by the U. S. Geological Survey a quadrangle is the area of cc covered by a topographic sheet of the Atlas of the United States.

of it may be called biotite-granite-gneiss. Ilmenite was found in the granite-gneiss, but not in the more massive granite. As the granite-gneiss has, after shearing and compression, undergone recrystallization, the ilmenite may possibly be secondary. At some points the crushing, shearing and recrystallization has been so thorough that the original massive granite has been converted into a moderately fine-grained gneiss.

Analyses have been made of this granite collected at three different points. These analyses show but slight variation in composition. There is also given an average of these three analyses, and from this the molecular composition has been calculated. Analysis 164 is of a biotite-granite which is regarded by Lindgren[4] as representative of the biotite-granite of Pyramid

ANALYSES OF BIOTITE-GRANITE

	1452 S. N.	1485 S. N.	2136 S. N.	Average of Nos. 1452, 1485 and 2136	Molecules of average	164 Pyramid Pk.
SiO_2	70.43[1]	70.75[1]	71.08[2]	70.75	1.1792	77.68[3]
TiO_2	.24	.42	.22	.29	.0036	.14
ZrO_2	....	....	.08	.03	.0002	....
Al_2O_3	15.51	15.13	15.90	15.51	.1521	11.81
Fe_2O_3	.96	.98	.62	.85	.0053	.72
FeO	1.28	1.43	1.31	1.34	.0193	.51
MnO	trace	trace	.15	.05		trace
NiO	?	none	....	....	....	....
CaO	2.76	3.09	2.60	2.82		.72
SrO	.05	.04	.02	.04	.0532	....
BaO	.20	.12	.04	.12		....
MgO	.37	.73	.54	.55	.0137	.18
K_2O	5.14	3.62	4.08	4.28	.0455	5.00
Na_2O	2.75	3.05	3.54	3.11	.0501	2.96
Li_2O	trace	trace	trace	trace	....	....
H_2O below 110° C.	.08	.10	none	.06	....	.04
H_2O above 110° C.	.40	.51	.30	.40	.0222	.27
P_2O_5	.11	.10	.10	.10	.0007	.10
CO_2	none	none	trace	....	....	....
FeS_2	trace	.06	....	.02	....	....
SO_3	....	....	none	....	....	....
Cl	....	....	.02	.02	.0005	....
Total	100.28	100.13	100.60	100.34	1.5456	100.13

Analyst: [1] Hillebrand. [2] Valentine. [3] Steiger.

[4] Am. Jour. Sci., Vol. III, 1897, p. 307.

Peak quadrangle. It will be noted, however, that the descrip tion of the rock by Lindgren indicates that it approximates i texture to a granite-porphyry, and that the chemical compositio is nearer that of an aplite than of the biotite-granite to the south c the Pyramid Peak district. I myself have not observed the latt to pass into porphyritic forms with a fine-grained groundmas

The calculation of the mineral composition is made in th following way. All of the phosphorous pentoxide (P_2O_5) ascribed to apatite. All the magnesia (MgO) is ascribed biotite. The molecular ratio of the oxides in the biotite is ca culated from an analysis of biotite separated from biotite-grani No. 2136, and as the biotite in all the biotite-granite is optical similar, it is fair to assume that it has, in all three of the granit averaged, sensibly the same composition. After deducting t titanium oxide (TiO_2) required for the biotite, the remaini titanium oxide is ascribed to titanite. All the zirconium oxi (ZrO_2) is calculated as zircon. After deducting the pota (K_2O) in the biotite, all the remainder is calculated as in pota feldspar. All the soda (Na_2O) in the rock is supposed to present in the albite. The chemical analysis[1] of the biot however, shows that it contains a little soda (0.38). In cal lating the ratio of the oxides in the biotite, the soda was pla

Composition of the biotite-granite, deduced from the average analysis above given		Pyramid Peak, 1(Lindgren
	Per cent.	Per cent.
Quartz	33.06	39.80
Potash-feldspar	20.70	28.17
Soda-feldspar	26.19	25.09
Lime feldspar	12.91	2.47
Biotite	5.64	3.10
Magnetite	.69	.61
Titanite	.55	.35
Apatite	.24	.25
Zircon	.01	......
Water	......	.31
	99.99	100.15

[1] Am. Jour. Sci., 1899.

with the potash. As the biotite forms only about one twentieth of the rock, the error in ignoring the soda in the biotite is small, and would not sensibly alter the result. If, however, the biotite forms a considerable part of the rock, its soda content should be separately calculated and the amount of soda in the biotite deducted from the total sóda, the remainder being considered as in albite. After deducting the lime (CaO) for the apatite, titanite, and biotite, the remaining lime is calculated as in anorthite. The oxides of strontium and barium are placed with the lime. After deducting the iron-oxides (Fe_2O_3 and FeO+MnO) for the biotite, all the remaining iron oxides are calculated as in magnetite. After deducting the silica (SiO_2) for the titanite, biotite, and feldspar, all the remaining silica is calculated as quartz.

GRANODIORITE

The granitoid rocks of the Sierra Nevada that were intruded at the close of Jurassic time, may be regarded as portions of one great batholith that may be supposed to underlie the entire range. The quartz-monzonites hereafter described are not regarded as belonging to the granodiorite batholith. All of the areas of this batholith are not connected at the surface, but it is more than probable that these separated areas are merely extruded tongues or gigantic apophyses of the main mass. Viewed from this standpoint, the variation of the chemical and mineral composition of this batholith is extraordinary. The rocks range from acid quartz-diorites containing over 70 per cent. of silica through quartz-mica-diorites, quartz-hornblende-diorites and quartz-pyroxene-diorites to gabbros and even olivine-gabbros. That these different rocks may be regarded as facies of one magma, appears to be indicated by the usual absence of sharp contacts and the existence of transition forms between them. The table of analyses given below probably represents very accurately the chemical variation of the rocks of the batholith. While the authors of the Gold Belt folios have always had in mind, as the typical granodiorite, a rock intermediate between granite and

diorite, in actual use the term in some of my own folios has been applied to all the rocks of which analyses are given in the table, so far as field mapping is concerned, although as a rule gabbro, even when genetically related to granodiorite proper, has been separated. Since the term has been so extensively used for quartz-diorites containing orthoclase, it is thought better to restrict the term to this usage and to call the rocks which are strictly intermediate between granite and diorite, quartz-monzonite.

While there is some doubt as to all of the areas called granodiorite in the folios being actually all portions of one magma, yet there is so great a variation within so many of these areas that the fact that the magma is a greatly variable one i established independently of the consideration of the batholitl as a whole.

The evidence that the areas ascribed to this great batholit were intruded at nearly the same time is not altogether satisfac tory, but at all places it points in the same direction. That to say, wherever the granolites composing the batholith com into contact with other rocks, excepting those of post-Jurass age, it is usually evident that they have metamorphosed tho rocks, indicating that they are intrusive in them and are of lat age. West of Mariposa the granodiorite has cut off and met morphosed the Jurassic Mariposa slates into chiastolite- ar mica-schists. At Mineral King, in the heart of the Sier Nevada, to the west of Mt. Whitney, is a lens of Juratrias sec ments which has been metamorphosed by granodiorite. Tl evidence is good that the great bulk of the pyroclastic met augite-andesites of the foothills are of Juratrias age. That tl granodiorite is intrusive in these rocks at some points, and h metamorphosed them, is evident in the field, as for exampl north and east of Mormon Bar in Mariposa county, where tl meta-augite-andesite-tuffs have undergone a thorough recry tallization. In Plumas county, southeast of Sierra City, t Juratrias rocks of the Milton formation have likewise be

metamorphosed by granodiorite; also north of Genesee Valley[1] there is a quartz-gabbro which is a basic facies of the great batholith, and the adjoining Triassic slates have been metamorphosed into hornfels. There is also evidence that the rocks of this batholith are later in age than the serpentines and associated magnesian rocks. This is particularly evident in the Bidwell Bar quadrangle, where the rocks of the magnesian series are cut by dikes of granodiorite, and in general throughout this quadrangle the rocks surrounding the granodiorite areas, whether of sedimentary or of igneous origin, show contact metamorphism. However, in the Bidwell Bar quadrangle the age of the sedimentary rocks, so far as known, is Carboniferous, and it can therefore only be said that in this region the granodiorite is post-Carboniferous.

In a paper[2] published in 1893, Lindgren describes typical granodiorite as follows: "The rock consists in typical development of feldspar, quartz, biotite, and hornblende with medium-grained hypidiomorphic structure. The soda-lime-feldspars are usually considerably and to a variable extent in excess of the alkali-feldspars. The silica varies between 60 and 73 per cent.; the amount of lime is variable, but it rarely exceeds, while it usually falls somewhat short of, the sum of the alkalies. While in some varieties which cannot be distinguished from the others in the field, there is more potash than soda, a frequently occurring relation is 2 per cent. Ka_2O to 4 per cent. Na_2O. It will be seen that the rock very closely approaches some quartz-mica-diorites and often might be indicated by that name."

In his later paper on the gold quartz veins of Nevada City and Grass Valley, published in the Seventeenth Annual Report of the U. S. Geological Survey, Lindgren gives the limits of chemical variation and average composition of granodiorite as follows.

[1] DILLER, Bull. 150 U. S. Geol. Surv., p. 338.

[2] The Auriferous Veins of Meadow Lake, California. Am. Jour. Sci., Vol. XLVI, 1893, pp. 202, 203.

In his investigation of Pyramid Peak quadrangle, Lindgre found large areas of granitic rocks containing amphibole and bi tite and resembling granodiorite in a general way. Some of the rocks are somewhat basic and probably correspond to the gran diorite of the Gold Belt region in chemical composition; but oth areas contain more alkali and less lime than the typical gran diorite of this paper. Lindgren, however, concluded that tl alkali-rich rock should be called the typical granodiorite, inasmu as it occurs in very large areas, and also since it occupies a pla almost exactly intermediate between quartz-diorite and grani Since that time much field work has been done in the south cent Sierra Nevada where the granular complex is finely exposed, m of the soil and loose rock having been removed by the glaci that formerly covered the region. The opportunities, therefore, studying the relations of the granites in this section are une celled. The different granitic rocks resemble one another so mu in general aspect that the contacts between different kinds a sometimes discovered only after careful search. As a rule a p son will pass from one kind of granite to another without havi observed any change in the rock until the difference is called his attention by some striking feature. It is not to be wonder

LIMITS OF VARIATION AND AVERAGE COMPOSITION OF GRANO-DIORITE

	Limits of variation	Average composition
	Per cent.	Per cent.
SiO_2	59 to 68½	65
Al_2O_3	14 to 17	16
Fe_2O_3	1½ to 2¼	1.50
FeO	1½ to 4½	3
CaO	3 to 6½	5
MgO	1 to 2½[1]	2
K_2O	1[2] to 3½	2.25
Na_2O	2½ to 4½	3.50
Remainder	....	1.75
		100

[1] Three and one half in one analysis.

[2] Certain masses in the foothills go below 1 per cent.

at, therefore, that the relations of the different granites is not yet clearly understood. The exposures at a number of points clearly show that the granodiorite proper is intrusive in, and therefore younger than, the biotite-granite. Other exposures near Yosemite Valley show a sharp contact between the rock here called quartz-monzonite and granodiorite proper. While the evidence of these two rocks being distinct is not altogether satisfactory at present, it is probable that the quartz-monzonite is later in age than the granodiorite. In order to show the chemical relations of granodiorite to related rocks, some partial analyses are here given:

		Granodiorite series		Quartz-monzonite		103 Pyramid Peak
	Tonalite	Quartz-diorite	Granodiorite	Banatite	Adamellite	
Silica	66.91	57.74	65.48	64.39	68.39	67.45
Alumina	15.20	17.36	16.05	15.90	13.47	15.51
Lime	3.73	6.81	4.88	4.15	3.24	3.60
Magnesia	2.35	3.62	2.13	1.93	1.02	1.10
Potash	.86	2.01	2.43	3.57	3.28	3.66
Soda	3.33	3.07	3.49	3.48	3.85	3.47

The rock described by vom Rath and called tonalite, has sometimes been regarded as a synonym for granodiorite. That such is not the case, however, will appear from the analysis given above. If this analysis is reliable it is clear that tonalite is a typical quartz-diorite unusually rich in silica. The analysis of the tonalite is the mean of two analyses by Kenngott.[1] The specimen analyzed came from Avio See and vom Rath,[2] who originated the name, analyzed the plagioclase of the tonalite of Adamello, and found the feldspar to be basic andesine

The quartz-diorite analysis may be regarded as a fair average of the smaller granodiorite areas noted in the Gold Belt folios and of the marginal portions of larger areas. This analysis is the mean of five basic quartz-diorite analyses given in the large table of granodiorite analyses.

[1] Zeit. Geol. Ges., Vol. XVII, 1865, p. 572.

[2] Zeit. Geol. Ges., Vol. XVI, 1864, p. 249.

ANALYSES OF ROCKS FROM THE POST-JURASSIC GRANODIORITE BATHOLITH OF THE SIERRA NEVADA

	Olivine gabbro	Basic quartz-diorites					Granodiorites proper					Acid quartz-diorites	
	No. 941 S. N.[1]	No. 1495 S. N.[2]	No. 225 S. N.[2]	No. 936 S. N.[2]	No. 851 S. N.[3]	No. 691 S. N.[1]	No. 369 S. N.[2]	No. 17 S. N.[2]	Grass Valley[2]	Nevada City[2]	No. 71 S. N.[2]	No. 303 S. N.[2]	No. 22 S. N.[2]
SiO_2	43.41	55.86	57.26	57.80	58.09	59.68	62.62	63.43	63.85	66.65	67.33	68.65	70.36
TiO_2	.39	1.20	.53	.70	.95	.65	.55	.73	.58	.38	.36	.28	.20
Al_2O_3	23.15	19.30	16.51	16.43	17.46	17.09	17.51	14.20	15.84	16.15	15.93	16.34	15.47
Cr_2O_3	none	....	none	none	....	none	.. .	....	....	....	....	....	....
Fe_2O_3	3.72	.91	3.27	1.62	1.12	2.85	.49	1.54	1.91	1.52	1.90	.93	.98
FeO	4.39	4.78	5.19	6.51	5.08	2.75	4.06	4.56	2.75	2.36	1.59	1.48	1.17
MnO	.08	.16	.18	.18	none	trace	.05	.03	.07	.10	.09	.08	trace
NiO	none	trace	trace?	.03	....	none	....	....	....	....	....	....	....
CaO	14.27	7.31	6.69	7.21	6.24	6.62	5.49	5.51	4.76	4.53	4.09	3.07	3.18
SrO	none	.04	.06	trace?	.04	trace	trace	trace	trace	trace	trace	.07	trace
BaO	none	.13	.10	.09	.07	.04	trace	.06	.06	.07	.08	.09	.06
MgO	7.65	2.94	3.41	4.14	4.06	3.54	2.84	2.35	2.07	1.74	1.63	1.29	.87
K_2O	.22	1.52	2.93	2.29	2.02	1.31	1.76	2.19	3.08	2.65	2.46	1.85	1.71
Na_2O	.82	3.52	2.65	2.35	2.94	3.87	3.49	3.49	3.29	3.40	3.76	4.85	4.91
Li_2O	trace	trace	trace	trace	none	trace	trace	none	trace	trace	trace	trace	trace
H_2O below 110° C.	.18	.19	.20	.11	.29	.15	.22	.15	.28	.18	.19	.24	.06
H_2O above 110° C.	1.53	1.23	.95	.38	1.45	1.00	.92	1.50	1.65	.72	.66	.62	1.00
P_2O_5	.02	.38	.30	.19	.17	.25	.12	.11	.13	.10	.11	.15	.11
CO_2	.10	none	none	none	.21	.20	....	....	....	....	....	....	....
FeS_2	.14	.39	none	none	c. .11	none	....	....	.04	.02	....	....	....
SO_3	....	....	....	....	.05	trace	....	....	....	....	....	....	....
Cl.	trace	....	....	....	.02	.03	....	....	....	....	....	....	....
F.	....	....	....	....	trace	none	....	....	....	....	....	....	....
Total	100.09	99.86	100.23	100.03	100.37	100.03	100.12	99.85	100.36	100.57	100.18	99.99	100.08

Analyst: [1] Stokes, [2] Hillebrand, [3] Steiger.

The granodiorite analysis may be regarded as typical of that rock and as representing the average rock of many areas. The analysis is the mean of the five analyses given in the large table. A comparison with the banatite analysis indicates a close relationship, but a granodiorite very seldom attains so high an alkali content as that of a banatite. The banatite analysis is a mean of five analyses by Brögger.[1] The analysis of the adamellite is a mean of six analyses by Brögger.[2] The quartz-monzonite analysis 103 Pyramid Peak is Lindgren's typical granodiorite of his latest paper.[3] It is clear that this rock would be placed with the monzonites by Brögger.

Granodiorite when typical is composed of plagioclase (oligoclase-andesine, but usually andesine) > quartz > orthoclase. Biotite and green aluminous amphibole are abundant constituents, but are variable in their relative amounts, and at times only one of these ferro-magnesian elements is present. Magnetite, titanite, and apatite are nearly always present as accessories. The rock is usually evenly granular in texture and of a light gray color.

Half Dome

QUARTZ-MONZONITE

As has already been stated under granodiorite, there are very large areas of a rock containing amphibole and biotite which resembles granodiorite and perhaps may be related to it genetically. From the analyses given below it will be seen, however, that the rock is richer in alkali and poorer in lime than the most acid of the granodiorites of the Gold Belt. This rock forms part of the east wall of Yosemite Valley and Half Dome, North Dome, Starr King, and other points. In general it is quite massive and thus lends itself to a method of weathering called exfoliation, which ordinarily results in the production of domelike forms. It is composed of oligoclase > quartz > orthoclase > biotite > amphibole. There are present as accessories titanite, apatite, iron ore, and zircon. It thus strongly resembles grano-

[1] Die Eruptionsfolge der triadischen Eruptivgesteine bei Predazzo, p. 62.

[2] *Ibid.*, p. 62.

[3] Am. Jour. Sci., 1897.

ANALYSES OF GRANITIC ROCKS

	Quartz-monzonite			Porphyritic quartz-monzonite	Soda-granite and aplite			Quartz-diorite aplite	Quartz-diorite
	No. 2179 S. N.	No. 1751 S. N.	No. 103 Pyramid Peak	No. 39 S. N.	No. 399 S. N.	No. 413 S. N	No. 725 S. N.	No. 1490 S. N.	No. 1495 S. N.
SiO_2	66.83	66.91	67.45	66.28	73.18	74.21	76.00	69.66	55.86
TiO_2	.54		.58	.54	.25	.30	.04	.21	1.20
ZrO_2	.04								
Al_2O_3	15.24		15.51	16.03	13.66	14.47	14.88	17.57	19.30
V_2O_3		.01 [1]							
Fe_2O_3	2.73		1.76	1.80	.21	.35	.65	.21	.91
FeO	1.66		2.21	1.88	2.24	.50	.10	1.04	4.78
MnO	.10			.05	.07	none	trace	trace	.16
NiO							none	none	trace
CaO	3.59	3.51	3.60	3.75	2.10	1.71	.19	4.54	7.31
SrO	.03			trace	trace	trace	none	.05	.04
BaO	.11			.08	.10	none	trace	.03	.13
MgO	1.63		1.10	1.12	.93	.28	.06	.58	2.94
K_2O	4.46	3.13	3.66	3.49	2.72	.10	2.77	.71	1.52
Na_2O	3.10	3.59	3.47	4.10	3.70	7.62	3.52	4.91	3.52
Li_2O	trace	trace		trace	trace	trace	none	none	trace
H_2O below 110° C.	none		.14	.11	.10	.15	.20	.05	.19
H_2O above 110° C.	.56		.63	.39	.57	.23	1.42	.50	1.23
P_2O_5	.18		.12	.30	.09	.07	.11	.03	.38
CO_2	trace				.17		none	none	none
FeS_2								trace	.39
SO_3	none								
Cl	.02								
F									
Total	100.82		100.25	99.92	100.09	99.99	99.94	100.09	99.86
Analyst	Valentine	Stokes	Steiger	Hillebrand	Hillebrand	Hillebrand	Stokes	Hillebrand S = trace	Hillebrand S = 0.21

diorite in mineral composition. One of the chief differences is the more acid character of the plagioclase which is, so far as known, always oligoclase. It also contains zircon, which is not usually found, and certainly is not abundant, in granodiorite. It is probably, moreover, of later age. The quartz-monzonite of the Sierra Nevada would be called a hornblende-biotite-granite by Rosenbusch. The three analyses given in the table below indicate that the chemical composition of this rock is remarkably uniform. The quartz-monzonite of the east wall of Yosemite Valley appears to be in sharp contact with the granodiorite mass that lies immediately west. At any rate the transition from the even-grained monzonite with scattered amphiboles to the more basic granodiorite, occurs within a very few feet at a number of points. More investigation, however, is needed.

The adoption of the term quartz-monzonite instead of granodiorite will perhaps be objected to by some petrographers on the ground that granodiorite is the older term. As has been shown, however, the latter rock does not occupy a strictly intermediate position between granite and quartz-diorite unless we extend the range of its chemical variation so as to include the quartz-monzonite of the higher parts of the Sierra. If we should confine the term quartz-monzonite, or granite-diorite, to quartz-feldspar rocks in which the potash and soda-lime feldspar are present in about equal amount, as Brögger has done, we would then have to exclude from this type nearly all of the rocks called granodiorite (quartz-orthoclase-diorite) in the Gold Belt folios. It would, therefore, seem better to let the term granodiorite stand for the rocks for which it has been used, and use one of the perfectly definite terms quartz-monzonite or granite-diorite for the rocks intermediate between granite and quartz-diorite. The term monzonite has already been adopted by the United States Geological Survey for folio use, and it seems, therefore, desirable for the members of the survey likewise to use the term quartz-monzonite for monzonites containing abundant quartz, in the same way that we use quartz-diorite for diorites containing abundant quartz.

THE PORPHYRITIC QUARTZ-MONZONITE[1]

Forming large areas along the higher parts of the rang coarse granitic rock containing numerous porphyritic ortho which are often more than two inches in length. This rock sharp contact with the quartz-monzonite, above described, northwest of Lake Tenaya in the Yosemite Park, and dou at other points. While not differing much in chemical con tion (see No. 39, table of analyses) from the latter roc marked porphyritic character and the usual absence of a bole readily distinguish it. Along the contact, however, th phyritic quartz-monzonite sometimes contains abundant a bole. The orthoclase phenocrysts are evidently formed late period in the consolidation of the rock, for these cont inclusions most of the minerals of the groundmass, incl plagioclase, biotite, quartz, titanite, and iron oxide. The sions have no definite arrangement in the phenocrysts.

BRIDAL VEIL GRANITE

In the drainage of Bridal Veil Creek, on Horse Ridg at many other points in the Yosemite Park, there are cor able masses of a white, rather fine-grained granite whic been designated Bridal Veil granite. It often shows an ort structure, there being a central white nucleus composed of and feldspar, surrounded by a layer rich in biotite. This g is intrusive in the biotite granite and often contains near th tact chunks of the latter. It also incloses fragments of d rocks, which are likewise found as nodules and small ar

ANALYSES OF BRIDAL VEIL GRANITE

	No. 2558 S. N.	No. 2051 S. N.
SiO_2	71.45	69.81
CaO	2.40	2.31
K_2O	3.25	5.25
N_2O	3.53	2.79

[1] Fourteenth Ann. Rep. U. S. Geol. Surv., pp. 478–480.

some of the other granites. No complete analysis has been made of this granite, but there are given above two partial analyses which indicate some variation in chemical composition if they are in reality both from the same magma.

No. 2558 is from north Cathedral Rock in Yosemite Valley, and No. 2051 is from a dike in the bed of the Middle Tuolumne River, about 4.5 kilometers northeast of Bald Mountain. Both analyses were made by Dr. H. N. Stokes.

SODA-GRANITE AND APLITE

Granitic rocks rich in soda are not abundant in the Sierra Nevada. The largest mass known lies east of Cathay Valley in Mariposa county. This area is clearly later than the diabase that is found to the west. Along the contact in and southeast of Cathay Valley a contact-breccia has been formed which is a mile or more in width. This is composed of fragments of the diabase cemented by the soda-granite. On the northeast the aplite area is in contact with the slates of the Mariposa formation. These slates are flinty near the contact on Agua Fria Creek, where also they are of a peculiar light gray color. Microscopic examination does not show any very marked metamorphism. Near the contact, however, the granitic rock is richer in lime (analysis 399, S. N.), which it may have absorbed (?) from the slates. The rock may also be regarded as a basic contact facies due to differentiation. In either case the above facts suggest that the granite is later in age than the Jurassic Mariposa slates. No. 399 was collected on Agua Fria Creek near the Mariposa slates, 5.2 km southwest of Mariposa. It is composed of micropegmatite, quartz, oligoclase, biotite, ilmenite, and epidote. Orthoclase is probably present although not determined in the thin section. Some of the epidote is wedged in between the other constituents all of which are fresh. This epidote is probably primary.

No. 413 is from the interior of the area above described, 6.5 km west of Mariposa. This was estimated to be a fair average sample of the rock. It is composed largely of albite and micro-

pegmatite, with less quartz, titanite, apatite, epidote, pyroxen‹ and uralite. A rough calculation shows that this rock is com posed of about 64 per cent. of albite, 25 per cent. quartz, th remaining 11 per cent. including pyroxene, titanite, apatite, ep dote and uralite. It is thus a true soda-granite.

South of the locality at which 399 was collected, on Agu Fria Creek, the soda-aplite is in sharp contact with granodiorit but there was no satisfactory evidence found of the relative ag of the two rocks. At the head of Owen's Creek, to the we of Cathay Valley, there is better evidence of the age of th soda-granite. The clay slates, which are pretty certainly ‹ Juratrias age, are here clearly metamorphosed by the granit rock.

In Butte and Plumas counties white dikes are abundant metamorphic magnesian rocks, which are altered peridotites ar pyroxenites. These dikes are mostly composed of quartz ar albite, but in some muscovite is present. Analysis 725 is of specimen collected from a dike in serpentine on Grizzly Hill Plumas county. It is composed chiefly of spherulites of qua and albite, micropegmatite, and abundant muscovite, the latt mineral chiefly in little rosettes. It has elsewhere[1] been su gested that these dikes of soda-granite and aplite are in sor way genetically related to the peridotites and pyroxenites other basic rocks with which they are usually associated.

The aplite dikes in the gneisses and associated granites.— In t bed of the North Mokelumne and other points there are irregu white dikes in the gneisses and associated granitic rocks. So of these dikes are of evenly granular texture throughout, a may be called aplites; others are banded. A chemical analy has been made of only one of these dikes, and this analy taken in connection with the microscopical examination in‹ cates that the rock is rich in soda, and hence the aplites in t gneisses are placed with the soda-aplites. It is by no mea certain, however, that they are all alike in composition. Some these dikes contain garnets. The aplites in the gneisses ar

[1] Bidwell Bar folio of the Atlas of the U. S. Geol. Surv.

The chemical analysis given below shows more titanium oxide than is required for the biotite. Inasmuch as all the iron oxide is magnetic and therefore probably magnetite, it is likely that there is no ilmenite present. The remaining titanium oxide is therefore supposed to be present in titanite, which is the most common titanium mineral in the Sierra Nevada granites. This mineral was not, however, found in the thin sections. The relative proportions of these different minerals are taken from the calculation, as given below.

It is well known that as a general rule, the less siliceous elements crystallize out first and the more siliceous last in rock magmas. In most quartz-diorite and granitic magmas the alkali-feldspar and quartz are usually the last elements to crystallize, and they are, also, the most acid of the components of the rock. A possible explanation of the occurrence of aplite dikes in quartz-diorite and granitic magmas would appear to result from this law of crystallization. We have but to suppose that after the crystallization of the less siliceous constituents there is a residual mass of orthoclase and quartz in solution which is afterwards forced into fractures which form in the already consolidated granite, perhaps as the result of cooling. The laws of thermochemistry would appear to be applicable to such a scheme. Heat would be generated by the crystallization of the minerals of the granite and this heat would perhaps aid in establishing convection currents to transport the residual, more siliceous, constituents away from the already consolidated material. Moreover, as suggested by Dr. Hillebrand, the more siliceous material would be crowded away by the minerals which crystallize first, in the same way as the salt of sea water is crowded out by the crystallization of the water, so that the residual sea water, after a portion has crystallized or frozen, contains more salt, proportionately, than the sea water before crystallization began.

The following calculation of the relative molecular proportions of the various minerals found in the granodiorite-aplites is based on the average of two complete chemical analyses by Dr. Hillebrand, given in the table below. The calculation is

1730 may be stated as follows: oligoclase> quartz> mi(cline> biotite.

Quartz-diorite-aplite.—In the bed of Bear River, Big Tı quadrangle, there are small white dikes from two to ten ce meters or more in width, occupying straight fissures in gn and quartz-diorite. The dikes have an aplitic texture and much more acid than the quartz-diorite. It may be assur that they bear a genetic relation to the diorite, similar to t existing between the potash-aplites hereafter described and granodiorite and quartz-monzonite. In the table of analy with the soda-granites there is given the chemical composit of one of these dikes (No. 1490) as well as that of the qua diorite (No. 1495) in which they occur. No. 1490[1] is pra cally an aplite, the feldspar, however, being probably chi andesine. The enclosing quartz-diorite is quite basic and we t have a suggestion that the composition of aplitic dikes is de mined by the composition of the granitic rock in which they oc Rosenbusch[2] refers to tonalite-aplite and diorite-aplite ; the dikes above described might be designated tonalite quartz-diorite-aplite, following Rosenbusch. It should be not however, that by some authors the term aplite is restricted granites composed chiefly of quartz and alkali-feldspar. however, dikes occur in various magmas which, while varying composition, show a direct genetic relation to these magn some group term for such dikes is desirable.

The potash-aplites and pegmatites of the granodiorite series.—A great number of points in the Sierra Nevada, there are dikes c white rock from a few inches to a few feet in width. In granodiorite and quartz-diorite these dikes are usually medi grained with only occasional dark constituents. They gr over into pegmatite. The pegmatitic facies will, however, treated in a later paragraph. This aplitic granite is compo of quartz> potash-feldspar> soda—lime-feldspar (oligoclase biotite> magnetite> apatite.

[1] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 704.

[2] Mikroskopische Physiographie der massigen Gesteine, 1896, p. 464.

The chemical analysis given below shows more titanium oxide than is required for the biotite. Inasmuch as all the iron oxide is magnetic and therefore probably magnetite, it is likely that there is no ilmenite present. The remaining titanium oxide is therefore supposed to be present in titanite, which is the most common titanium mineral in the Sierra Nevada granites. This mineral was not, however, found in the thin sections. The relative proportions of these different minerals are taken from the calculation, as given below.

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The following calculation of the relative molecular proportions of the various minerals found in the granodiorite-aplites is based on the average of two complete chemical analyses by Dr. Hillebrand, given in the table below. The calculation is

made in the same way as for the biotite-granite. The biotite in the aplites being similar to that of the biotite-granite, it is supposed to have the same chemical composition. The result of the computation is as follows.

COMPOSITION OF THE GRANODIORITE-APLITE

	Molecules	Percentage
Quartz - - - - -	.6058	39.45
Potash-feldspar - -	.4520	29.43
Soda-feldspar - - -	.3536	23.03
Lime-feldspar - -	.1008	6.56
Biotite - - - - -	.0138	.90
Magnetite - - -	.0061	.40
Titanite - - - - -	.0027	.18
Apatite - - -	.0008	.05
	1.5356	100.00
Total molecules	1.5523	
Not accounted for	.0167	

ANALYSES OF POTASH APLITES

	159 Nevada city	No. 227 S. N.	No. 161 S. N.	Average of 227 and 161	Molecular proportions of the average
SiO_2	77.05 [1]	75.97 [2]	76.03 [2]	76.00	[illegible]
TiO_2	....	.09	.07	.08	[illegible]
Al_2O_3	....	13.07	13.39	13.23	[illegible]
Cr_2O_3	....	none	....	....	....
Fe_2O_3	....	.61	.48	.54	[illegible]
FeO	....	.39	.31	.35	[illegible]
MnO	....	trace	trace	trace	[illegible]
NiO	....	none	....	....	....
CaO	.73	1.49	1.28	1.38 } 1.49	.0266
SrO	....	.03	trace	.02	
BaO	....	.14	.04	.09	
MgO		.14	.05	.09	.0022
K_2O	5.06	5.62	5.18	5.40	.0574
Na_2O	3 43	2.51	2.08	2.74	.0442
Li_2O	....	trace	none	....	....
H_2O below 110° C.	....	.14	.15	.14	....
H_2O above 110° C	....	24	34	.29	.0161
P_2O_5	....	trace	.03	.02	.00014
CO_2	....	none	....	....	....
Total		100.44	100.33	100.37	1.5523

Analyst: [1] **Stokes.** [2] **Hillebrand.**

159, N. C. is taken from Lindgren's paper in the Seventeenth Ann. Rep., U. S. Geol. Surv., Part 2, p 45.

227, S. N. Dike in quartz-mica-diorite (No. 225, S. N.) about 3.2 km. east of Milton in the Downieville quadrangle The dike is about 60 cm. wide.

171, S. N. Dike in the quartz-mica-diorite about 11 km. east of the Sierra Buttes, Downieville quadrangle. The dike is quite wide and is intersected by joints, the most prominent set being nearly vertical.

Pegmatites.—The pegmatites which are associated with granodiorite and quartz-monzonite are very often banded, the border

FIG. 1.—Boulder of aplite-pegmatite on ridge south of Highland Creek in the Big Trees quadrangle.

of the dike being aplite and the middle layer pegmatite, thus forming a suggestion of the "comb" structure shown in some quartz veins. In certain cases the banding is repeated, there being several layers of aplite with pegmatite between. This is

shown in Fig. 1. In the more acid dikes or veins (?) middle band is quartz with aplite borders.

It is not yet ascertained whether the aplites and peg tites occurring in the different granites of the Sierra Ne show characteristic differences that are constant. The ol clase-aplite (No. 1730), previously described as coming f the North Mokelumne River, was presumed in the field to typical of the aplites of the gneisses and biotite-granite; it remains to be shown if there is not considerable diversit these dikes. There are, for example, in the Yosemite q rangle, in biotite-granite, sporadic bunches of white platy qu interspersed with chunks of flesh-colored orthoclase or m cline. This forms practically a coarse pegmatite. The qu in these bunches greatly exceeds in amount the potash-feld so far as my observation goes. One bunch of white quart the trail to the "Fissures" south of Yosemite Valley is 18 me long and 14 wide, with chunks of potash-feldspar; but tenths of the mass is quartz. Some of the pegmatite in bio granite is distinctly banded,[1] the same as in granodiorite.

H. W. TURNE

[1] Seventeenth Ann. Rep., U. S. Geol. Surv., Part I, p. 700, Plate XXXIV.

STUDIES FOR STUDENTS.

THE DEVELOPMENT AND GEOLOGICAL RELATIONS OF THE VERTEBRATES.

V. MAMMALIA.—(*Continued.*)

HIPPOIDEA, *Equidae.*—The phylogeny of the horses has been made out by a study of the gradual changes which succeeded one another in the development of the modern form of the teeth and the foot structure. A nearly perfect series of these changes is known, and besides the direct line of the development of the horse, there have been demonstrated several side lines, all of which have become extinct. The earliest form that can be definitely stated as belonging to the line of the horses is *Hyracotherium*, from the Lower Eocene of the continent of Europe, England, and the United States. It is to be noticed that it does not occur in the lowest Eocene; thus it is not found in the Puerco of the United States, with the *Condylarthra*, but is found in the Wasatch, Green River, and the Bridger. There are four digits on the front foot and five on the hind foot, the three middle digits being functional on both feet; the fibula and the ulna of the fore part of the front and hind limbs are fully formed, and show nothing of the reduction that they subsequently undergo. The upper molars are different from the premolars, and are furnished with six tubercles, an outer pair and an inner pair, and between these another pair that is smaller.

Pachynolophus is from practically the same horizons as the *Hyracotherium* in America and on the continent. It represents a short step in advance; the ulna and the fibula are smaller and barely reach the end of the radius and the tibia. The two inner tubercles of the teeth are elongated laterally and almost join the two middle ones. This form includes, according to Osborn,

a large number of genera from both the old and the new wor that have been described from separate teeth and fragmen bones.

Epihippus from the Uinta and Bridger and *Propaleotheri* from the Middle Eocene of the Paris Basin, are very close the *Pachynolophus*, but the inner tubercles of the upper mol are more perfectly joined to the middle tubercles, so that th is a short ridge on both the anterior and the posterior portion the inner side of the tooth.

Mesohippus from the Oligocene of the United States, Wh River, and *Paleotherium* from the Upper Eocene and the Oli cene of France, are the best representatives of the next st In these forms there are only three digits on the front and h feet, the fourth digit on the front foot being reduced to a m splint bone with no trace of terminal phalanges. The ulna the fibula are greatly reduced and scarcely reach to the distal e of the radius and the tibia. The connections between the inner sets of tubercles of the upper molars have developed i strong cross ridges which extend well out to the outer borde the tooth and nearly touch the anterior edges of the correspo ing tubercles.

Anchitherium is now regarded as little off the main line descent of the true horses, but as it represents very closely succeeding stage that is properly indicated by a poorly kn form, *Desmatippus*, from the Deep River beds of Oregon, it properly be described here.

Anchitherium is one of the most common forms of the Up and the Middle Miocene of the continent of Europe and United States. The fourth digit of the front foot is reduce a mere ossicle of bone at the upper end of the third digit. distal ends of the ulna and the fibula have entirely disappea so that the bone ends free in the middle part. The teeth sl the cross ridges of the upper molars extending out to the o tubercles and joined with them. One of the most impor changes of the series that developed the horse appears in form; the enamel on the upper portion of the cross ridges

appears and permits the cement below to appear at the surface. Now, as the cement is softer than the enamel, the wear of the tooth will serve to keep this inner part lower than the enamel walls, and there will always be sharp edges to serve for grinding up the grass and other herbage that forms the food of the animal.

Protohippus and *Merychippus* from the Pliocene of North America are the next forms in the series. The two lateral digits of the feet, two and four, are shortened and do not reach the ground, though they still retain all the phalanges. The ulna and the fibula are reduced to short splints, confined to the proximal ends of the radius and the tibia. The molars are very horse-like in the fact that all the tubercles have lost the enamel from the upper surfaces, and there are great "lakes" of cement, bordered by sharp enamel edges, for grinding the food.

Hipparion is a form somewhat off the line of the horses, but differs little from the *Protohippus*. It was very common in the Miocene time both in North America and in Europe. It extended up into the Pliocene in Africa and Asia.

Pliohippus and *Equus* are from the Pliocene deposits of most of the world, and from there upward the deposits of the Pleistocene and the recent times show their presence, except that *Pliohippus* is absent in the Recent. It is of interest to note that though the continent of North America was undoubtedly the original home of the horses and the theater of their greatest development, that at the end of the Pleistocene time they seem to have disappeared from the continent, and were only reintroduced by man when the Spaniards brought them over to aid in the conquest of Mexico.

The last two genera are distinguished by the reduction of the two lateral digits to two splint bones on the proximal end of the cannon bone and the nearly complete loss of the ulna and the fibula; the latter remains only as the olecranon process.

The phylogeny of the horse series has thus been arranged by Mr. Farr, a late writer on the subject.

Pliocene to Recent *Equus*

Hippidium

Loup Fork	*Protohippus*
	Hipparion
Deep River	*Desmatippus*
	Anchitherium
John Day	*Mesohippus*
White River	*Mesohippus*
Uinta	*Epihippus*
Bridger	*Pachynolophus*
Wasatch	*Hyracotherium*
	Paleotherium
Puerco	*Condylarthra*

The earliest of the horses must have presented a very different appearance from the horse as we know it. They were scarcely larger than a small dog and had rather the appearance of one than of a horse. The Miocene members of the group were about the size of a small pony, with very delicate limbs. According to Osborn, they were, in all probability, marked very much like the zebra. The *Anchitherium*, *Hipparion*, and the earliest true horses were somewhat smaller than the recent horse, but could not have been very different in their external appearance.

Paleotheridae.—This is the more primitive of the two families. It is known only from the Upper Eocene deposits of Europe, but there are several closely related later forms both in Europe and America. *Anchitherium* and *Pachynolophus*, described among the *Equidae*, are by some authors regarded as more closely related to the *Paleotheridae*.

Paleotherium, from the Upper Eocene of the Paris Basin, is the typical genus. The dentition is complete, but the premolars have assumed the appearance of molars. There were three toes on each foot, all reaching to the ground. The surfaces of the teeth are covered with enamel and have not begun to show the "lakes" of cement that characterize the teeth of the true horses. The largest, from *P. magnum*, was about the size of a rhinoceros.

The TAPIROIDEA has the two families *Tapiridae* and *Lophiodontidae*. In common with the other Perissodactyls, they seem to

have their origin in the earliest Eocene from some animal closely related to the *Hyracotherium*. In general they were stout-bodied animals of medium size, with three digits on the posterior foot and four on the anterior; the upper teeth developed in the more recent forms a pair of transverse parallel ridges that are characteristic of the group.

Early in the history of the group it divided into the two families, which took different lines of development, the *Tapiridae* working out the condition of the modern Tapirs and the *Lophiodontidae*, which assumed somewhat the characters of the rhinoceroses and became extinct in the late Eocene or Middle Miocene.

Tapiridae. — The line of development of the modern Tapirs is expressed as follows by Wortman and Earle: *Systemodon* of the Wind River; *Isectolophus latidens*, Bridger; *I. annectens*, Uinta; *Protapirus*, White River, and possibly *Tapiravus*, of the Loup Fork. Speaking of this family, Smith Woodward says: "The family thus characterized dates back to the Lower Miocene (White River Formation) in the United States of America, and apparently to the same remote period in Europe. In the Tapirs of this early date the premolars are slightly simpler than those of he surviving genus *Tapirus;* while *Tapiravus*, ranging through he Miocene and Pliocene of North America, is still somewhat rimitive in the same feature. The typical *Tapirus* itself, however, is represented in Europe by several fine specimens from ne Lower Pliocene of Eppelsheim, Hesse-Darmstadt (*T. priscus*), and from the corresponding formations in Hungary and outheastern Austria; also by remains from the Pliocene of rance and Italy, and by detached teeth from the Red Crag of uffolk. It is also to be noted that other teeth, indistinguishable from those of *Tapirus*, occur in an Upper Tertiary (probably liocene) formation in China. It is thus evident that during iocene and Pliocene times these animals ranged over most of e warm and temperate lands of the northern hemisphere. ence is explained the remarkable distribution of the existing apirs, which are confined to two widely separated areas, namely,

(1) certain portions of the Indo-Malayan region, and (2) t
tropical parts of America."

Lophiodontidae.—In defining this family Osborn and Wor man indicate its position by referring to it as "A family Lophodont Perissodactyls intermediate in position between th *Tapiridae* and the *Hyracodontidae.* The genera referred to th family are *Lophiodon* from the Middle Eocene of Europe, *Hept don* of the Wasatch, *Helaletes* of the Bridger and Uinta, ar *Colodon* of the White River.

Lophiodon has been considered as a very widely spread for in the Middle Miocene of Europe, but it now seems to be tl opinion that many species have been wrongly referred to it th should properly be placed with genera *Colodon* and *Helaletes.*

The CHALICOTHEROIDEA is sometimes regarded as a separa suborder, the *Ancyclopoda* not being related directly to the Per sodactyls. They were aberrant animals related on the one ha to the Perissodactyls and on the other to the Edentates. In t structure of the foot there is a striking resemblance to the stru ture in the great ground sloths, *Gravigrada,* of the late Tertiar of America. It was five-toed and turned so that the weight the animal rested upon the outer side of the foot, and the dig terminated in strong claws. The teeth, on the other hand, w strikingly like the teeth of the Perissodactyl series. The su order, or super-family, had its greatest development in the M cene and Pliocene times.

Homalodontotherium is from the early Tertiary deposits Patagonia. The primitive character is indicated by the compl dentition of the animal and the absence of any diastema. T humerus was very short and stout, indicating possible fosso habits.

Macrotherium is a smaller form from the Middle Miocene France and Germany. The condition of the teeth indicate somewhat more advanced type. The fore limbs were mu longer than the hind. The best known species was about n feet in length.

Chalicotherium is the best known form from the United Stat

It is found most commonly in the Loup Fork. Many teeth resembling *Chalicotherium* have been named from all parts of the world, notably China, Hungary, and Germany, indicating a very wide range for the genus.

From the Tertiary deposits of South America, in Patagonia, and the Argentine Republic come the remains of many animals that seem to be without representatives in any other part of the world. In some respects they resemble the Perissodactyls and, indeed, one of the orders is regarded by Zittel as a possible family of that group. Their relationships are, however, still too imperfectly known to permit of much discussion. Three orders are known, the *Typhotheria*, *Toxodontia* and *Litopterna* (*Proterotheridae* Zittel). Smith Woodward says they "must be little modified descendants of very primitive eutherian mammals."

TYPOTHERIA.—The order is peculiar among the ungulates, in that it possesses a well-developed clavicle. The limbs are unmodified and the dentition is nearly complete.

Pachyrucus and *Typotherium* are the best known genera. The first was somewhat the smaller of the two. The teeth are somewhat rodent-like in appearance and the dentition is not complete. There was a considerable diastema between the enlarged incisors and the premolars, the canines were wanting.

TOXODONTIA.—The second order of the South American group resembled in many of its characters the first, but lacked the clavicle, and the limbs were modified toward the ungulate type, there being but three toes on the fore and hind feet The animals were much larger than the previous order, reaching nearly the size of the rhinoceros in the genus *Toxodon.* The bodies of the animals were short and stout, and the head was placed on a very short neck low on the body. The two typical genera *Toxodont* and *Nesodon* are both from the Tertiary of South America, but *Nesodon* is from the earliest strata.

LITOPTERNA.—This order was much farther developed than the preceding, and in general appearance could not have been far from that of the modern horse. The primitive condition is indicated by the complete dentition and the stage of develop-

ment of the limbs. There were forms with only a single digit remaining, and others with three, resembling the Perissodactyls in this character, but the same animals had the tarsus built on the Artiodactyl plan so that they can belong to neither group.

Thoatherium and *Proterotherium* are small animals from the Santa Cruz formation of Patagonia. They were monodactyl, the second and fourth digits being either completely lost or greatly reduced in size.

Macrauchenia was much larger than the other two, and resembled the modern camel in size and some of the skeletal characters. The limbs were functionally tridactyl. The genus comes from the Pleistocene deposits of Argentina.

AMBLYPODA.—This suborder reached its greatest development in the Eocene time and died out at the close of the same period. The members of the suborder were all rather stout animals that reached, near the time of their extinction, the size of an elephant, or nearly so. The brain was very small and almost devoid of convolutions; there were five toes on each of the feet, and the bones of the limbs were complete, *i. e.*, the tibia and the fibula, and the radius and ulna, were separate and perfect. The group is generally divided into two families according to the characters of the teeth, skull and limbs.

Coryphodontidae were animals limited to the lowest Eocene of America, England and France. The greatest number and the most perfect specimens have been obtained from the Wasatch formation of the western part of the United States.

Coryphodon, the typical genus, was a short and rather stout animal about six feet long; the skull was elongated in the facial region with a rather broad muzzle armed with strong incisor and canine teeth; the feet were very short and strong with blunt toes. The brain cavity was very small and limited to a small part of the skull. The surface of the skull was without any bony excrescences or with only very faint ones.

Dinocerotidae: found in the Middle Eocene, Bridger; animals larger than the preceding family, and in general stouter and stronger. The skull was longer and without the anterior

enlargement of the muzzle; the dentition was weaker in that the incisors were lost entirely or in part, and the molars and premolars were small and weak. The canines were greatly enlarged and extended from the jaws as tusks that were protected by a flange of the lower jaw. The top of the skull shows three pairs of bony protuberances that were possibly the bases of horns. The brain was little, if in advance, of that of the *Coryphodontidae*.

Dinoceros (*Unitatherium*).—Characters given in the description of the family.

ARTIODACTYLA.—The families that we shall consider are the *Anthracotheridae*, the *Suidae*, the *Oreodontidae*, the *Hippopotamidae*, the *Camelidae*, the *Anoplotheridae*, the *Tragulidae*, the *Protoceratidae*, the *Cervicorna*, and the *Cavicorna*.

Anthracotheridae.—This is an extinct family that is found chiefly in the deposits of Europe and the East Indies. The earliest member of the group occurs in the Eocene of Europe. During the Miocene time it spread over the whole continent of Europe and over North America. The whole group appears to have died out in the Miocene. The animals were large, about the size of the rhinoceros, and from that down to the size of a pig. The head was long and low, with little development in the cranial region and a consequently small development of the brain. The teeth are of the low multitubercular type that is characteristic of the pig family. The feet have four toes on each foot and the metapodials of the middle pair are not united.

Anthracotherium, Oligocene, of Europe, England, and India, and North America.

Ancodus, Oligocene, of Europe, and North America.

Merycopotamus, Pliocene, of India.

Suidae.—This is a very large group that contains the existing hog. There are many primitive characters in the group, such as the complete dentition, and the generalized multituberculate teeth. The limbs have either four or two toes and the metapodials of the middle pair are not united. The living members of the family are found in Asia, Africa, Europe, and America.

Fossil forms of the group are found in the Eocene of Europe and North America, but the greatest development of the family came from the Pliocene to Recent. The origin of the *Suidae* is not at all well known, but there seems to be little doubt that they are the specialized branch of some carnivorous stem.

Achænodon, from the Bridger Eocene, has very strong canine: and the cheek teeth are similar in many respects to those of th primitive *Carnivora*.

Elotherium, from the Oligocene of Europe and the Unite States, White River, is one of the ancestral forms. The head i long, the posterior teeth are multitubercular, the premolars ar conical, and the canines and incisors are long and well fitted fc grasping. The limbs were peculiarly long, and altogether th animal seems to have been a rather vicious type of carnivoro hog that had the running powers of a deer.

Platygonus, from the Pliocene and the Pleistocene of tl United States, was a very small form that seems to have been tl direct ancestor of the peccary.

Sus, the true hog, appeared in Europe and Asia, in the Upp Miocene and has continued ever since. There is no nati member of the genus in the Americas.

Hippopotamidae.—The Hippopotamus is not known earlier th the Pliocene, and occurs in deposits of that age in England a in India. The existing forms are confined in Africa.

Oreodontidae.—This is an extinct group that is confined to t Miocene and the lower Pliocene of the United States. It primitive in all of its characters; the dentition is complete a the fore limb has five digits; the metapodials are not unite One peculiar thing is that the anterior lower premolar toc passed forward and acted as the canine, while the canine assum the aspect and the function of an incisor. The sense of heari was very acute, the bulla of the ear reaches, in some of the la forms a very large size. The animals were all small, ne reaching a size larger than that of a Newfoundland dog, and most cases were much smaller. From the manner of the occ rence of their remains it seems that they lived near the ban

of the lakes or streams and gathered together in great herds. The time of their greatest development was the Oligocene, and in the beds of the White River deposits the remains are found in the greatest abundance.

Protoreodon.—Uinta.

Agriochoerus.—White River, a peculiar form that had the toes terminated in sharp claws like the Sloths.

Oreodon.—White River.

Leptauchenia and *Cyclopedius.*—Upper Miocene, Deep River.

Camelidae.—The camels seem to have developed first on the North American continent in the Middle Eocene, Uinta, and Bridger, and to have died out in the Pliocene. They are peculiar in the much elongated head and the deficient anterior dentition. In the older forms the metapodials are separate as in the families already described, but in the later ones the two are joined and only a thin layer of bone separates the two medullary cavities.

In South America during the Pliocene time there were developed a large number of forms that became extinct, with the exception of the existing Llama. The genus *Camelus* appeared in Asia in the Lower Pliocene without known forerunners, and in North Africa at the beginning of the Pliocene.

Leptotragulus.—Unita.

Poebrotherium.—White River.

Protolabis.—Loup Fork.

Procamelus.—Loup Fork.

Anoplotheridae.—Small extinct forms that were developed in the Eocene of Europe and died out in the lower Miocene. They seem never to have extended beyond the limits of the continent of Europe. They were among the first to develop the selenodont form of teeth that is the characteristic form of the deers and the most of the ruminants.

Anoplotherium.—Eocene.

Dichobune.—Eocene.

Xiphodon.—Eocene.

Cænotherium.—Miocene.

Tragulidae.—Small forms that began in the Eocene of Europe and spread over nearly all parts of the world in the Miocene and the Pliocene. *Tragulus* of the East Indies and *Hyæmoschus* of the west African region are still living members of the group.

The group is highly specialized. The median metapodials alone are functional, the second and fifth are reduced to mere splints at the upper and lower ends of the middle pair. The carpals and tarsals are united in some forms and the metapodials are elongated and united in many of the forms to a cannon bone. The elongation of the limb, due to the length of the metapodials indicates the great running and leaping powers of the form. The upper incisor teeth are wanting and in the males the upper canine is elongate and appears outside of the mouth as a long tusk.

Lophiomeryx.— Europe, Upper Eocene.

Prodremotherium.— Europe, Upper Eocene. Remarkable for the slender skeleton and the length of the limbs.

Gelocus.— Europe, Oligocene.

Dremotherium and *Amphitragulus.*— Lower Miocene, Europe.

Dorcatherium.— Miocene, Europe and Asia.

Leptomeryx and *Hypertragulus.*— North America, Miocene.

Tragulus appeared in the Pliocene of Asia, and *Hyaemoschus* is unknown from fossil remains.

Protoceratidae.—A small family resembling in many respects the *Tragulidae* of the old world. The group is confined to the upper part of the White River formation of the United States. There is only one well-known genus, the *Protoceras*, an animal that resembled the modern antelope, probably, as much as any recent form. The male is peculiar in the fact that the skull bore two or three pairs of horn cores. The female was without horns.

Cervicorna.—This essentially modern group appears in the Miocene of Europe and North America and has a considerable number of the members still living. The males have, in nearly every case bony horns that are shed every year, differing in this respect from the succeeding group in which there is a permanent horn core, and the horn proper is not shed. The upper incisors

are deficient or entirely absent, and the upper canines are either absent, small, or enlarged as in the *Tragulidæ*. The carpals and the tarsals are anchylosed in some forms and the metapodials are united to form a cannon bone. The whole structure of the skeleton indicates the lightness and the speed of the deer tribe.

Blastomeryx.—North America, Miocene and Pliocene.

Paleomeryx.—Europe, Miocene.

Helladotherium.—Europe and Asia, Upper Miocene. This form with the *Samotherium* of Europe are interesting as being the ancestors of the giraffe, *Camelopardalis*, which is found in the same deposits and then disappears from the record to appear again in the Recent in Africa.

Sivatherium and *Bramatherium* are large forms, strikingly resembling the moose, which are known from the Miocene deposits of India and unknown since.

Most of the modern forms of the family seem to have appeared in the Pliocene and their remains are especially well preserved in the European deposits, but not until the Pleistocene time do the deposits indicate anything like the profusion of numbers and the widespread distribution of the group that obtains at present.

Cavicornia.—The group is in few particulars different from the *Cervicornia*. The horns are not deciduous or bony, they are present in both sexes. The teeth are similar in many respects, but the upper canine is always lacking as well as the upper incisors. The metapodials are always united to form a cannon bone and the lateral digits are the merest rudiments or are completely absent. In general the skeleton is very similar to that of the preceding group, but in many of the forms it is much more robust. One thing characteristic of the group is the width of the brow. Where the horns are set close together in the *Cervicornia*, in this group they are wide apart, a condition that reaches its greatest development in the *Bovidae*, the cows and buffaloes. It is of interest to note that the same loss of the enamel which took place on the upper surface of the teeth of the *Equidae* also took place in the *Artiodactyla*, and the later

forms have the enamel entirely removed from the tops of the tubercles and the spaces between the walls filled up with a softer and more rapidly wearing cement.

Three general divisions may be recognized, the antelopes, the sheep and the bovine tribe. The oldest of these, the antelopes, appeared in the Miocene of Europe and southern India. They seem to be derived directly from the *Cervulinae*, a subfamily of the *Cervicornia* represented by *Dremotherium* and *Amphitragulus*. During the Pliocene the three groups were differentiated.

Pliocene.	Antilopinæ. Ovinæ. Bovinæ.
Upper Miocene.	Antilopinæ.
Lower Miocene.	Cervulinæ. Dremotherium and Amphitragulus.

PROBOSCIDEA.—The origin of this suborder is not at all well understood, the first members of the group are found in the Miocene time and in all the essential characters are as well developed as the most advanced of the living forms. In many of their characters the *Proboscidea* are very primitive; the structure of the feet and of the carpus and tarsus, the structure of the limbs and other parts of the body, are such as are found in the earliest ungulates. The development of the proboscis and the correlated shortening of the neck and the development of the peculiar dentition are the only characters that define the group. The most characteristic feature is the development of the incisor teeth as tusks which in some forms occur in both the upper and the lower jaws, in others in the lower jaws, and in the most modern forms in the upper jaws. In the earliest forms there were many teeth in the jaws, each one with strong transverse ridges completely covered with enamel; in the advance of the group the ridges on the teeth seemed to multiply until they became very numerous, and at the same time the enamel disappeared

from the top of the ridges, leaving the softer dentine exposed, which wore away more rapidly than the enamel and left strong, grinding ridges such as are found in the horse. With the advance in the structure of the teeth appeared the degeneration of the dentition as a whole, so that the modern elephant has never more than one cheek tooth at a time in the jaw; the teeth appear successionally, the anterior one first and so backwards during the life of the animal.

Dinotherium is the earliest known member of the group. It was characterized by the development of a pair of down-curving tusks in the lower jaw and a complete absence of incisors in the upper jaw. There was a more or less complete dentition, the jaw containing two premolars and three molars. The single complete skull known is about three feet long. The genus is known from the Miocene of Bohemia and from the Pliocene of Central Europe and India. It is unknown from America.

Mastodon differed from the preceding in the presence of fewer molar teeth and in the presence of tusks in both the upper and lower jaws or in the upper jaw alone. The molar teeth exhibit many variations in form, but in general the surface has a tendency to be distinctly tuberculated, the transverse ridges multiplying and dividing into outer and inner halves. In size the animal was nearly as great as the elephant. It was very common in the later Tertiary and forms have been discovered in formations as early as the Middle Miocene in Central Europe. In the Pliocene the genus seems to have reached a wonderful development and to have ranged over the greater part of the world; forms have been discovered in nearly every part of the world that man has visited. Near the close of the Pliocene it disappeared from Europe, but is found in the Pleistocene of America, sometimes associated with flint implements.

CARNIVORA.—The order *Carnivora* is one of the best known from the fossil forms. In the earliest Eocene they approach the *Condylarthra* to an extent that makes it difficult to tell the lines of the Ungulates and the Unguiculates (claw-bearing forms)

apart. The earliest of the *Carnivora* are placed in a suborder, the *Creodonta* opposed to the suborder *Carnivora vera* which includes the recent Carnivores and their immediate ancestors.

Creodonta.—These animals show their approach to the carnivorous type by the development of specialized cutting teeth, the appearance of claws on the feet and the assumption of the general form of the modern carnivores. Recent investigations show that this suborder is perhaps the most primitive of the modern mammals and is to be considered the ancestor of the ungulate type. Osborn, in a discussion of the questions of paleontology, said: "The most primitive type of Condylarth (*Euprotogonia*) and of Amblypod (*Pantolambda*) as recently studied by Osborn and Matthew, strongly reinforces the hypothesis first enunciated by Cope, *that the source of the Ungulata is to be found in the Creodonta.* Upon the other side of the great Mammalian tree, the numerous branches of Unguiculates or primitive clawed types also have converged towards a Creodont ancestry, as seen especially in the characters of the Ganodonta, or ancestral Edentates, and of the Rodentia, if Matthew's supposition proves to be correct also of the Tillodontia. Thus all these groups should be added to the Carnivora as Creodont derivatives. The Carnivora extend back into Creodont prototypes; but, as in the case of the Artiodactyla and the Perissodactyla, the actual points of contact or links between the two divisions are yet to be discovered." He extends the discussion to the position of the Creodonta with relation to the primates. He says: "The point of contact of the primates with the Creodonta is still entirely wanting, but their relations appear to be here rather than with the Insectivora.

"In spite, therefore, of the many remaining deficiencies or absence of links in our paleontological evidence, it has none the less come about *that the Creodont type takes the central position which was assigned by Huxley in 1880 to the Insectivora,* for the known Creodonta are more generalized and more central than any other of the known Insectivora, fossil or living, the known Insectivora showing a very considerable specialization, especially

in their dental succession, which places them apart as a distinct side phylum. This does not affect the derivation of the Creodonta themselves from stem forms of unspecialized Insectivora existing in the Jurassic period, the characters of which are seen in the *Insectivora Primitiva*, or placentals of the Stonesfield Slate and Purbeck periods."

The *Creodonta* are generally divided into eight families, which are here arranged as nearly as possible in the order of their evolution, which was directed toward the development of more perfect sectorial teeth and more and deeper convolutions on the surface of the brain.

Arctocyonidae: from the lowest Eocene of the United States, Puercö and Wasatch and the lowest Eocene of France.

Oxyclænidae: from the lowest Eocene of the United States.

Triisodontidae: from the lowest Eocene of the United States.

Mesonchyidae: from the Lower and Middle Eocene and possibly from the Miocene of the United States.

Proviverridae: from the Eocene of Europe and the United States.

Paleonictidae: from the Lower Eocene of the United States. This family is of some interest as containing the possible ancestor of the pinniped group of the true Carnivores.

Hyænodontidae: from the Eocene to the Miocene of Europe and America. This family has well-developed teeth of the sectorial type and approaches very close to the true carnivores.

Miacidae: from the Eocene of the United States. This family so closely approaches the modern carnivores that they have been placed among them by certain authors.

From the Lower Tertiary deposits of South America, Patagonia, come many forms that are undoubtedly Creodonts but of doubtful position in the suborder; by some authors they are placed among the *Hyænodontidae*, and by others they are placed in a separate group, the *Sparrassodonta*. The best known forms are *Prothylacinus* and *Borhyæna;* they are very similar in some respects to the carnivorous Marsupial, *Thylacinus*, of Tasmania.

The *Carnivora vera* are distinguished by the larger size of the brain with its deeper convolutions and the development of a single tooth in each jaw, the fourth premolar in the upper jaw and the opposing first molar in the lower jaw, as sectorial teeth. The suborder is generally divided into two groups : the *Fissipeda* or land living forms and the *Pinnipeda*, seals, walruses, etc.

Fissipeda. — Seven families are recognized, the *Canidae*, *Ursidae*, *Procyonidae*, *Mustelidae*, *Viverridae*, *Hyænidae* and *Felidae*.

Canidae.—The dogs appeared in the Upper Eocene of Europe and the Lower Miocene of the United States. They are descendants, probably, of the Proviverrine branch of the *Creodonta*. The development of the dogs has been toward the improvement of the feet as organs of locomotion; the early forms had five toes on both the fore and the hind feet, but in the modern forms the first digit is wanting on the front foot and often on the hind foot as well. The teeth have developed from low crushing forms to the more typical carnivorous condition with the specialized carnassials. Typical forms are :

Cynodictis and *Cephalogale*, Upper Eocene, Europe.

Amphicynodon, Oligocene, Europe.

Amphicyon and *Galecynus*, Miocene, Europe.

Daphænos and *Oligobunis*, North American Miocene.

The recent forms appeared in the Pliocene of Europe, Asi and North America, and in the Pleistocene of Africa and Sout America.

Ursidae.— The bears are distinguished by the plantigrade fe and the low multitubercular teeth without the specialized carna sials. They appeared in the Middle Miocene of Europe in tl genus *Hyænarctos* and not before the Pleistocene in the oth countries when the existing genera were developed.

Procyonidae.— The coons occupy a small place somewhe between the dogs and the bears. They were developed sor time in the Pliocene and are today confined to the Ame can and the South Asian regions. They are known from t Loup Fork beds of the United States.

Mustelidae.— The weasels and otters are among the mc

specialized of the *Carnivora.* The first live almost entirely upon blood drawn from the veins of their victims and the second are aquatic in habit and great eaters of fish. They began their development in the upper Eocene and in that time and the Miocene a large number of forms were developed in Europe. After the Miocene they spread out and the deposits of all parts of the world, with the exception of Australia, are rich in their remains.

Viverridae.—A small group of cat-like animals confined to Africa, Asia and Southern Europe. They originated in the Eocene of Europe and only as late as the Pliocene appeared in others countries.

Hyænidae.—The hyænas are somewhere between the cats and the bears, the teeth are partly sectorial and partly crushing in form. They appeared in the Upper Eocene of Europe and Asia and are now known from those deposits with the addition of North Africa. *Hyænictis* is one of the first forms. It is from the Miocene of Europe and Asia.

Felidae.—The cats reach, perhaps, the highest point of the development of the *Carnivora.* The teeth are highly specialized; the molars seem to show a tendency to grow less in number and to assume more and more the form of the feline carnassials which are the highest type of that tooth form developed. The fore feet are modified to serve as organs of prehension as well as locomotion. The canine tooth reaches enormous proportions in some forms, and there is a process on the lower jaw to protect them as in the *Dinocerata.* They originated in the Upper Eocene and rapidly spread all over the world. The Oligocene, White River, of the United States is especially rich in the remains of these forms.

Eusmilus.—Upper Eocene of Europe.

Hoplophoneus, *Dinictis*, *Nimravus* and *Pogonodon.*—White River, United States.

Machairodus.—Pliocene, Europe, Asia, and the Americas. This form is remarkable for the great length of the upper canine. It was so long that it is possible that the animal could

not open its mouth wide enough to bring the teeth into play. It has been suggested that the teeth were used to aid it in climbing trees.

The existing genera of the cats were developed in the Pliocene and Pleistocene.

Pinnipeda.—The water living carnivores seem to have sprung, as has been suggested, from the Creodont *Patriofelis.* The existing families can be traced back as far as the Pliocene but beyond that there is nothing to connect them with the early forms. Fragmentary skeletons of seals and walruses have been found in the Pliocene of Europe and America.

INSECTIVORA.—The Insectivores are among the least changed of all the Mammals from their prototypes of the earliest Tertiary. The brain, carpus and dentition all present characters that are found in the Creodonts. Many of the existing families are found in the Eocene.

CHIROPTERA.—The bats are known from deposits as early as the Eocene in Europe and America, but nothing is known of their ancestry; the fossil genera, including those extinct, are very similar to the living forms.

RODENTIA.—The order is characterized by the absence of the canine teeth, the development of two incisors in the upper and the lower jaws as gnawing teeth which grow from persistent pulps and the arrangement of the articular condyle so that the lower jaw can slide backward and forward in the act of grinding up the food. There are many primitive characters in the group which is a remarkably persistent one, well-defined rodents being known from the early Eocene. Three sub-orders are known: the *Tillodontia*, *Duplicidentata* and the *Simplicidentata*.

Tillodontia.—These are forms that are known from the Eocene deposits of Europe and America. In these the canines are still preserved as rudiments, and there are sometimes more than the single pair of incisors in the lower jaw.

Esthyonx from the Wasatch and Bridger series of the United States is the earliest form known. A fragmentary skull from

the London Clay seems to indicate the presence of a related form in Europe.

Tillotherium from the Bridger of the United States is the largest form known; the skull measured about a foot in length. The developed incisor teeth are of large size, and the second pairs of incisors and the canines are even smaller than in the preceding genus.

Duplicidentata.—This group contains the hares and rabbits. They seem to have been developed about the Middle Miocene, *Paleolagus*, White River. During the Pliocene they spread over all of Europe and North and South America.

Simplicidentata.—This group is far larger than the preceding; it contains the rats, mice, squirrels, and all the remaining forms of the rodents. None of the forms appear before the Miocene, and during that time and the Pliocene differentiated and spread all over the world.

PRIMATES.—The order is divided into two suborders, the *Lemuroidea*, containing the lemurs, and the *Anthropoidea*, containing the apes and man.

Among the primitive lemurs are many forms which are so clearly intermediate between the two suborders that they must be regarded as the direct ancestors of the *Anthropoidea*. The living lemurs are confined to the island of Madagascar and to parts of Africa and southern Asia. In the Miocene and Eocene times they seem to have spread over the greater part of Europe and North America; they became extinct in the latter countries about the end of the Miocene time. Among the most important forms of the lemurs are *Anaptomorphus*, *Adapis* and *Megaladapis*.

Anaptomorphus is from the Wasatch Eocene of Wyoming; related forms are known from the lower Eocene of France and England. The animal exhibits the very large cerebral hemispheres that are characteristic of all the Primates and thus indicates the starting point of the specialization in the nervous system that has culminated in man.

Adapis is from the Lower Eocene of Europe; a closely related form is *Tomitherium* from the Eocene of New Mexico.

Megaladapis is a very large form from the post-Pleistocene of Madagascar. The skull was about two feet long. The animal seems to have lived in the island as late as the seventeenth century.

Anthropoidea.—The true apes do not appear until the middle of the Miocene; in Europe they seem to have extended over a large part of the continent as late as the Pliocene time, and one genus still exists upon the rock of Gibraltar. The genera of the apes multiply so rapidly that it is not possible to trace the development of the forms in any limited paper. It will perhaps suffice to note their occurrence in the Middle Miocene of France, the Pliocene of Germany, the Pliocene and Pleistocene of India and the early Tertiary of Patagonia.

In regard to the derivation of the human family, *Hominidae*, from the Primates Cope says (*Primary Factors of Organic Evolution*, chap. 11, p. 157. The phylogeny of man): "To return to the more immediate ancestry of man I have expressed and now maintain as a working hypothesis that all the Anthropomorpha were descended from the Eocene lemuroids. In my system the Anthropomorpha includes the two families Hominidæ and Simiidæ. The sole difference between these families is seen in the structure of the posterior foot, the Simiidæ having the hallux (great toe) opposable, while in the Hominidæ the hallux is not opposable. . . . . " "It is then highly probable that Homo is descended from some form of the Anthropomorpha now extinct, and probably unknown at present, although we do not yet know all the characters of some extinct supposed Simiidæ, of which fragments only remain to us."

Smith Woodward says of the earliest men: "Most of the evidence for the existence of the human race in the pre-historic past consists in traces of intelligent handiwork revealed by stone and other implements. A few discoveries in the old world, however, are worthy of consideration.

"The oldest known traces of a man-like skeleton seem to be an imperfect roof of a skull, two molar teeth, and a diseased femur, from a bed of volcanic ash containing the remains of

Pliocene mammals, near Trinil, in central Java. These are believed to belong to one animal which has received the name of *Pithecanthropus erectus*. The capacity of the brain-case is estimated to have been about two-thirds the average of that of man: the forehead is very low; and the supraorbital ridges are prominent. The inclination of the nuchal surface of the occiput is considerably greater than in the Simiidæ. The femur measures 0.455 m in length, and denotes an upright gait.

"The oldest human skeletons of which the geological age is determined with certainty, are two from the cavern of Spy, near Namur, in Belgium. These were found in association with remains of the mammoth and other Pleistocene mammals beneath a layer of stalagmite, which had never been disturbed, and which was also covered with earth containing bones of the same extinct quadrupeds. The skeletons, therefore, could not be the result of a comparatively recent burial, but were proved to have been contemporaneous with the associated animals and Palæolithic flint implements. They are essentially human in every respect, but seem to represent a race inferior in skeletal characters to any now existing. They are small, but powerfully built. The forehead is low; the supraorbital ridges are very prominent; and the chin is remarkably retreating. The radius and ulna are unusually divergent in the middle. The femur is somewhat bent, and the tibia is comparatively short, so that the leg cannot have been quite upright in walking. This type is now generally known as the *Neanderthal race*, the roof of a simi-ar skull having been found associated with other fragmentary emains so long ago as 1857 in a cavern in the Neanderthal etween Düsseldorf and Elberfeld, Germany."

In closing the discussion of the mammals, it is well to draw ttention to the idea so forcibly set forth in Lydekker's book, *eographical History of the Mammalia*, that all the mammals had northern origin, and have attained their present position by adual migration toward the south. Though the theory is still r from being proven, it should be of great interest to the ıdent of geology because of the possibilities it presents for an

interpretation of climatic and land-mass conditions in the T
tiary time. Throughout the book evidence is constantly addu
to show the strength of the author's position. I shall qu
merely enough of the introduction to give an idea of
theory.

Upon page 7 the author says: "There is a consider
probability that at least a very large proportion of the anir
that have populated the globe in the later geological epo
originated high up in the northern hemisphere, if not, indeed
the neighborhood of the pole itself (which is known to h
enjoyed a genial climate during the Tertiary period), and
they gradually migrated southwards in a series of waves, pr
bly under pressure of the development of new and higher t
in high latitudes; and it is to such southerly migrations that
present marked differentiation of the fauna of different par
the earth's surface is chiefly due. Whether such a north
origin held good for the terrestrial life of the Secondary ep
there are no means of determining; but it would appear tha
higher animals (which were chiefly reptiles) of that epoch
very similar throughout the world, and that the differentiatio
faunas had scarcely, if at all, commenced." .... "With m
mals the case is very different. The earliest known forms, w
date from the Triassic and Jurassic rocks, are chiefly marsu
and forms apparently allied to the monotremes, and it is pr
ble that most of the descendants of these, as is more fully
cated in the sequel, migrated southwards during the early
of the Tertiary epoch, to find in Australasia a refuge from
competition of higher forms. Of the higher placental m
mals, none of the modern types make their appearance be
the Oligocene and Miocene periods, while many do not ante
the Pliocene. Their southern migrations accordingly took p
later on in the Tertiary period, one of the earliest movem
being the wandering of lemuroids, insectivores, and civet
carnivores into South Africa and Madagascar. On the o
hand, many other higher types, such as the hippopotami, gira
and antelopes, which were abundant in Europe and sout

Asia during the Pliocene, only left their more northern homes to find a permanent abiding place in Africa at a very late epoch in the earth's history."

E. C. CASE.

References.—Other than the books already referred to, the student will find the most helpful literature in the files and current numbers of *The American Journal of Science*, *The American Naturalist*, which contains a number of separate articles upon the different groups, by the late Professor Cope, the *Proceedings of the Philadelphia Academy of Science*, the *Proceedings of the American Philosophical Society*, *The American Geologist*, and *The Kansas University Quarterly*.

EDITORIAL

A PRELIMINARY circular of the French Committee of Organization for the Eighth Session of the International Geological Congress announces the date of the meeting to be held in Paris in 1900. The meetings will be opened on the 16th of August and will be closed on the 28th. They will be held in a building connected with the Exposition, and the hours will be so arranged as to give the members opportunity to visit the Exposition.

Field excursions are to be made a prominent feature of the session and will take place before, during, and after the meetings. These excursions are to be of two kinds, *general* and *special.* The first will be open to as large a number of members as possible, who may be taken to localities where hotel accommodations are adequate. The special excursions are intended for specialists, and since they may necessitate the visiting of regions poorly provided with hotels, the number of members who may participate in each excursion is limited to twenty. To compensate for the small number of geologists admitted to any one of these excursions, the number of excursions is increased to nineteen. This arrangement promises to be a satisfactory solution of the difficult problems connected with the geological excursions, which form so valuable a factor in the organization of the congress.

Of the general excursions three are announced:

1. Tertiary Basins of Paris, conducted by MM. Munier-Chalmas, Dollfus, L. Janet, and Stanislas Meunier.

2. Boulonnais and Normandie, conducted by MM. Gosselet, Munier-Chalmas, Bigot, Cayeux, Pellat, Rigaux — 10 days.

3. Central plateau of France, conducted by MM. Michel-Lévy, Boule, Fabre — 10 days.

The nineteen special excursions include:

I. Ardennes, conducted by M. Gosselet — 8 days.

II. Picardie, conducted by MM. Gosselet, Cayeux, Ladrière —6 days.

III. Bretagne, conducted by M. Barrois — 10 days.

IV. Mayenne, conducted by M. Oehlert — 8 days.

V. Turonian Types of Touraine and Cenomanian Types of Mans, conducted by M. de Grossouvre — 6 days.

VI. Faluns of Touraine, conducted by M. Dollfus — 4 days.

VII. Morvan, conducted by MM. Vélain, Peron, Bréon — 10 days.

VIII. Coal Basins of Commentry and of Decazeville, conducted by M. Fayol — 7 days.

IX. Massif of Mont-Dore, Chain of Puys, and Limagne, conducted by M. Michel-Lévy — 10 days.

X. Charentes, conducted by M. Glangeaud — 8 days.

XI. Basin of Bordeaux, conducted by M. Fallot — 6 days.

XII. Tertiary Basins of the Rhône, Secondary and Tertiary Terranes of the Basses-Alps, conducted by MM. Depéret and Haug — 12 days.

XIII. Alps of Dauphiné and Mont Blanc, conducted by MM. Marcel Bertrand and Kilian — 10 days.

XIV. Massif of Pelvoux (High Alps), conducted by M. Termier — 10 to 12 days.

XV. Mont Ventoux and mountain of Lure, conducted by MM. Kilian, Leenhardt, Lory, Paquier — 10 days.

XVI. Basse-Provence, conducted by MM. Marcel Bertrand, Vasseur, and Zürcher — 10 days.

XVII. Massif of Montagne-Noire, conducted by M. Bergeron — 8 days.

XVIII. Pyrénées (crystalline rocks), conducted by M. Lacroix — 10 days.

XIX. Pyrénées (sedimentary rocks), conducted by M. Carez — 10 days.

Further notice of the excursions and a guidebook relating to them will be issued early in 1900. J. P I.

SUMMARIES OF CURRENT NORTH AMERICAN CAMBRIAN LITERATURE[1]

Boss[2] describes the dikes associated with the ore depos Gogebic iron range. They are dioritic and more or less alte are approximately at right angles with the dip of the forma cut, and the greater number of them have an average easte $15°$ to $18°$— sometimes they are folded in such a manner as long synclinal basins with eastward pitch. In a majority mining exploitation has shown a succession of dikes, one other, and ferruginous quartzite of varying thickness im underlying each dike and forming the cap of the succeedin of ore.

Comment.—The dikes have been shown by Irving and V to be diabase, rather than diorite. With this exception, t observations are in accord with and confirm those of Irving Hise in this area, and except in a few details nothing new is p For a comprehensive discussion of the position of the dikes relations to the ore bodies the reader is referred to Monogr of the United States Geological Survey.

Wadsworth[4] describes the origin and mode of occurren Lake Superior copper deposits, and the age of the coppe series. A reëxamination of the Douglass Houghton and H River areas shows that the Eastern Sandstone passes under with increasing dip, and that the junction is not a fault jun that of a lava flow upon an underlying soft sand and mud. that the Eastern Sandstone is of Potsdam age, and underlies th bearing series, the first lava of that series having flowed out

[1] Continued from p. 854, Vol. VI, JOUR. GEOL.

[2] Some dike features of the Gogebic iron range, by C. M. Boss, Tran Min. Engineers, Vol. XXVII, 1898, pp. 556–563.

[3] The Penokee-Gogebic iron-bearing series of Michigan and Wisconsi IRVING and C. R. VAN HISE: Mon. U. S. Geol. Surv., No. XIX, 1892.

[4] The origin and mode of occurrence of the Lake Superior copper M. E. WADSWORTH: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 189 696.

sandstone. The basaltic rocks forming the Bohemian Mountains present phenomena which indicate their eruption subsequent to the formation of the main deposits of the region, although the question is as yet open. Subsequent to the deposition of the Keweenawan a fissure was formed near the contact of the Eastern Sandstone and the lavas, along which normal faulting occurred, the copper-bearing series forming the overhanging side of the fault. As to the nature of the displacement, however, more evidence is needed. The copper occurs in fissure veins, in melaphyres, and in conglomerates.

Comments.—That the Keweenawan was deposited on the Eastern Sandstone was held by Wadsworth before the publication of Irving's[1] report on the copper-bearing series in 1883. In his report Irving presented evidence to show that this could not be the case, but that the sandstone is post Keweenawan; and later, in 1885, Irving and Chamberlin[2] in a more comprehensive discussion of the relations of the Keweenawan to the Eastern Sandstone, proved still more clearly the post-Keweenawan age of the Eastern Sandstone. Subsequently, in 1893, Wadsworth took the view that the Keweenawan formed the lower part of the Potsdam, and explained the phenomena on the theory that the Eastern Sandstone, instead of being one sandstone, may contain two or three sandstones of different ages. In the article above reviewed Wadsworth has gone back to his earlier view. However, he has not yet met the arguments so clearly stated by Irving and later and more comprehensively, by Irving and Chamberlin.

Berkey[3] describes and maps the geology of the St. Croix dalles of Wisconsin and Minnesota. Keweenawan eruptives are exposed at numerous localities, and particularly along the river, where, by their erosion, they have formed the dalles of the St. Croix River. The dip is about 15° to the south, which would give a thickness to the rocks in sight of 4000 feet. At several localities the Basal Sandstone unconformably overlies the Keweenawan eruptives with visible contacts, the

[1] The copper-bearing rocks of Lake Superior, by R. D. IRVING: Mon. U. S. Geol. Surv., No. V, 1883.

[2] Observations on the junction between the Eastern Sandstone and the Keweenaw series on Keweenaw Point, Lake Superior, by R. D. IRVING and T. C. CHAMBERLIN: Bull. U. S. Geol. Surv., No. XXIII, 1885.

[3] Geology of the St. Croix Dalles, by C. P. BERKEY: Am. Geol., Vol. XX, 1897, pp. 348–383, and Vol. XXI, 1898, pp. 139–155, 270–294.

Basal Sandstone including the sandstone and shale series between the Keweenawan and the St. Lawrence shales.

Winchell[1] discusses the significance of the fragmental eruptive débris at Taylor's Falls, Minn. This has heretofore been regarded as a conglomerate resting unconformably upon the Keweenawan. As a result of recent field work by Mr. C. P. Berkey, it is believed that this conglomerate may be separated into two conglomerates, an upper one at the base of the upper division of the Cambrian, and a lower one at the base of the lower division. The latter would come within the Keweenawan, as this term is used by Irving and other writers, and would separate this series into two parts.[2] The later conglomerate rests directly upon the earlier one, leading to the previous confusion of the true relations. Similar conglomerates found in the Keweenawan at several points between Duluth and Grand Portage have led to the conclusion that the Keweenawan may be divided into two great series, separated by conglomerate and quartzite which reach a thickness of several hundred feet. The lower series has been included in the Norian, and the upper series comprising the sedimentaries and the eruptives above them, has been called Keweenawan, the Keweenawan forming the lower division of the Cambrian.

Comments.—While the conglomerate within the Keweenawan at this locality has not before been noted, the occurrence of many conglomerates at other localities in the middle and upper part of the Keweenawan has been mapped and described by the Michigan and United States geologists, as a glance at Marvin's Eagle River section[3] and Irving's general report[4] on the Keweenawan will indicate. Instead of one conglomerate, there are a dozen conglomerates at different horizons. However, these conglomerates are composed almost without exception of local material, derived wholly from contemporaneous lava flows, and are held to mark very insignificant breaks in the series. As seen from Winchell's description, the Taylor's Falls conglomerate belongs to this class. The United States geologists, recognizing the

[1] The significance of the fragmental eruptive débris at Taylor's Falls, Minn., by N. H. WINCHELL: Am. Geol., Vol. XXII, 1898, pp. 72–78.

[2] In a recent paper, above summarized, MR. BERKEY (Am. Geol., Vol. XX, p. 381) takes the view that the lower conglomerate is a flow breccia of the igneous rocks.

[3] Geology of Michigan, 1873, Vol. I, Part II, Copper-bearing rocks, pp. 117–140

[4] Copper-bearing rocks of Lake Superior, Mon. V, U. S. Geol. Surv., 1883.

local character of the conglomerates, have considered the series including them as a unit, and, regarding the hiatus at the top of the series as much more profound than that at the bottom, have included the series in the Algonkian, rather than in the Cambrian. Winchell and many of the Canadian geologists, on the other hand, have recognized but one conglomerate within the Keweenawan, and, giving this undue significance, have extended the Cambrian downward to this conglomerate, thereby including in the Cambrian the profound unconformity separating the Keweenawan series and the fossil-bearing Cambrian. If Winchell's reasoning be carried to its logical conclusion, wherever a conglomerate is found within the Keweenawan, the series must there be divided, and in place of one series, we shall have many series, a division which cannot be considered reasonable. It appears, therefore that Winchell's division of the Keweenawan into two series, on the basis of local conglomerates such as the one described from Taylor's Falls, is purely arbitrary, and furthermore, by referring his upper division to the Cambrian, the profound unconformity known to exist between the true Cambrian and the Keweenawan is practically ignored.

Winchell[1] discusses the Archean greenstones of Minnesota, which he considers the oldest known rocks, representing the original crust of the earth. The greenstones are divisible into two parts, one igneous and the other clastic, the latter succeeding the former with a confused, and apparently sometimes conformable superposition, somewhat as surface eruptive rocks might be superposed, in the presence of oceanic action, upon a massive of the same nature at the same place. The clastic portions of the greenstones vary to more siliceous rocks, constituting great thicknesses of graywackes, phyllites, and conglomerates, and as such have been converted by widespread metamorphism into mica-schists and gneisses.

As the Laurentian gneisses and granites cut the schists and sedimentary gneisses they are also younger than the bottom greenstones.

The metamorphic schists and gneisses seem to be representative of the sedimentary portion of the Lower Laurentian of Canada, while the igneous granite and gneisses are as plainly a general parallel of the igneous portion of that series. It follows, therefore, that the Canadian Laurentian is, as a whole, of later date than the greenstones, if the

[1] The oldest known rock, by N. H. WINCHELL: Proc. Am. Assoc. Adv. Sci. Vol. LXVII, 1898, pp. 302, 303 (Abstract).

succession is the same as in the Northwest, and that the greenstones should be considered the bottom rock of the geological scale.

Winchell[1] attempts to explain the origin of the Archean igneous rocks. From field evidence and petrographic discriminations and associations, it is believed that the alkaline magma from which the igneous rocks were derived is the result of aqueo-igneous fusion of the fragmentals of the Archean itself; that when deeply buried, under heat and pressure, the Archean clastics were rendered plastic, penetrating openings in the adjacent and superjacent strata; and that when the plastic mass was not moved from its place it was simply recrystallized *in situ*.

The clastic rocks must have been derived from the basal greenstone, which is considered representative of the original crust of the earth. The presence in such clastics of sufficient potassa and silica to yield upon fusion the granitic magmas is explained on the hypothesis that they must have come from the waters depositing the fragmentals, and primarily from the atmosphere, in its condition normal to the Archean age, just following the congealing of the first crust.

While numerous instances of such transition from clastic to igneous rock have been noted in Minnesota, there has been a careful study of but one. That was the case of the granite and porphyry which intrude the clastics at Kekequabic Lake.

Winchell[2] presents some additional points on the geology of northeastern Minnesota.

The Laurentian includes, in Minnesota, an acid crystalline schist of sedimentary origin, and a massive igneous rock, although the igneous rock is younger than the crystalline schist portion, and should have a different designation. The conclusions reached are that: (1) the sedimentary Laurentian is a crystalline condition of sedimentary strata, which are conformably a portion of the sedimentary schists; (2) the igneous Laurentian is the result of a more intense metamorphism, carried even to fusion of some strata. These conclusions result particularly from the study of a section from Tower northward, through Vermilion

[1] The origin of the Archean igneous rocks, by N. H. WINCHELL: Proc. Am. Ass. Adv. Sci., Vol. XLVII, 1898, pp. 303, 304 (Abstract). Also Am. Geol., Vol. XX, 1898, pp. 299–310.

[2] Some new features in the geology of northeastern Minnesota, by N. H. WINCHELL: Am. Geol., Vol. XX, 1897, pp. 41–51.

Lake, and of an area on the west side of Outlet Bay, in the corners of sections 13, 14, 21, and 32, T. 63 N., R., 17 W., and along the shore for one half mile westward.

It is evident that the Stuntz conglomerate on the south shore of Vermilion Lake is a true water-deposited conglomerate, of the same formation as the slates and graywackes of the district, the conglomerate grading into the quartzite and graywacke, and this into argillaceous slate. Furthermore, as supposed by Van Hise, the conglomerate lies unconformably on the iron-bearing formation, and contains very numerous fragments of jaspilite. The position of this unconformity, whether at the base of the Taconic or lower is not ascertained.

The nature and position of the conglomerate in the valley of the Puckwunge, a small stream entering the Pigeon River north of Grand Portage, is discussed. This conglomerate is overlain by igneous rocks, resembling the traps of the Keweenawan. The subjacent formation cannot be certainly determined, but in the same locality, at a lower level, is a slate rock, called the Puckwunge slate, which was followed for some distance north and east, and which is probably an upper member of the Animikie, not before individualized. The conglomerate contains quartzite pebbles, which are referable to the quartzites of the Animikie, farther north. It may be inferred that this is the basal conglomerate of the Keweenawan, which has been identified up to Grand Portage island, and at intervals along the Lake Superior coast, from Baptism River to near Beaver Bay.

Winchell[1] discusses some resemblances between the Archean of Minnesota and of Finland. The succession in northeastern Minnesota, as made out largely from field work done in 1897, is as follows, in descending order.

1. *Granitic intrusion*, cutting and metamorphosing the earlier schists and fragmentals. This rock is seen about Snowbank Lake and Moose Lake, about the western confine of Disappointment Lake, and at Kekequabic lake.

2. *Upper Keewatin.*—This consists of conglomerates (at Stuntz Island and at Saganaga and Ogishkie Muncie lakes), sericitic schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids. The mica-schists, embracing many conspicuous bowlder-

[1] Some resemblances between the Archean of Minnesota and of Finland, by N. H. WINCHELL: Am Geol., Vol. XXI, 1898, pp. 222–229.

like forms on the weathered surfaces, are to be seen about Moose Lake, and southeast to Snowbank Lake, about Disappointment Lake, Kekequabic Lake, and eastward to Zeta Lake.

3. *Granitic intrusion*, chiefly represented by the granite of Saganaga Lake, where the Upper Keewatin lies unconformably upon it. It is also seen a little west of Ely and on the Kawishiwi River. At West Seagull Lake this granite cuts older greenstones and green schists.

4. *Lower Keewatin or Kawishiwin.*—This is mainly a greenstone formation, both massive and fragmental, and constitutes the oldest formation in the state. When stratified it consists of basic tuffs, agglomerates, and green stratified schists and greenwackes. It contains the banded jaspylites and iron ores at Vermilion Lake. Where cut by granite and porphyry (1), these rocks are converted to mica-schist and banded gneiss.

Unconformably above all these is the Animikie formation, of Taconic age, the base of the Paleozoic.

Nos. (1), (2) and (3), above, are paralleled in Finland by similar rocks in similar order, as described by Sederholm. Rocks corresponding to No. (4), the Lower Keewatin, seem to be wanting, or are seen only as inclusions in the next younger granite.

It is probable that the divisions above detailed for Minnesota and Finland are wholly embraced in the lower division of the Canadian Laurentian, *i. e.*, in the Ottawa gneiss, and that they have not yet been noted in Canada. The fundamental gneiss of Canada is, therefore, not the bottom of the geological series, but is largely a sedimentary series, derived from an older series, this older series being in part at least a greenstone, as indicated by the stratigraphic succession in Minnesota.

Comments.— In the above papers Winchell has modified his ideas from time to time with reference to the general succession of the pre-Cambrian rocks of northeastern Minnesota, and it may be well briefly to summarize what appear to be his latest conclusions. The succession from the base upward is as follows: (1) greenstone, both massive and fragmental, called the Lower Keewatin ; (2) cutting this is a massive granite, typically developed at Saganaga Lake ; (3) unconformably above the Lower Keewatin is a series of sedimentary rocks, consisting of conglomerates, sericite-schists, quartzose and micaceous schists, graywackes, clay-slates, chloritic schists, and porphyroids, called the Upper Keewatin ; (4) granite cutting and metamorphosing all the preceding.

The correlation of the Minnesota series with the Ottawa gneiss and with the Finland series must be considered a pure conjecture. The Minnesota succession is not agreed upon; these widely separated regions have not been connected by structural work, and of course in the case of Finland never can be; and lastly, fossil evidence is lacking. Any correlation of the ancient crystalline rocks without the basis of connecting structural work or fossil evidence, must be considered as little more than a guess, having no foundation in inductive knowledge.

The massive igneous rocks of the Laurentian, mostly granites, which intrude the sedimentary rocks, are believed by Winchell to be due to the aqueo-igneous fusion of the lower portion of the sedimentary rocks, and the intrusion of the magma thus formed into the overlying sediments. The argument adduced in favor of this origin is based almost entirely upon an occurrence cited at Kekequabic Lake of a transition from igneous rocks to the clastic rocks there found. In 1891 and 1892 Grant[1] studied this area, and found no evidence of a transition from the semicrystalline and crystalline schists into granite. On the contrary, abundant evidence was found of the eruptive nature of the granitic rocks in the surrounding sedimentaries. The same area was closely studied by a party of the U. S. Geol. Survey during 1898, and the same conclusion was reached. The principal support of Winchell's theory is thus taken away, and it stands as an unproved hypothesis.

Grant[2] describes and maps the geology of Kekequabic Lake in northeastern Minnesota. By far the larger proportion of the rocks represented are clastics, which are divided for convenience into four groups. The first and most extensive group is the slate formation, consisting largely of argillites, with smaller amounts of fine and coarse graywackes and grits, the coarser phases becoming distinctly conglomeratic in places. The second group consists of coarse conglomeratic rocks, which are a part of the Ogishke conglomerate. The third group is made up of certain fissile green schists, which are believed to be water deposited, and probably originally formed from fine volcanic ash. The fourth

[1] Twentieth Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., 1893, pp. 69–82; and Twenty-first Ann. Rept., *ibid.*, pp. 50–54.

[2] The geology of Kekequabic Lake in northeastern Minnesota, with special reference to an augite soda granite, by U. S. Grant: A thesis accepted for the degree of Ph.D in The Johns Hopkins University, 1893. Published in Twenty-first Ann. Rept. Geol. and Nat. Hist. Surv. of Minn., for 1892, pp. 5–58, 1893. With geol. map and plates.

group consists of volcanic fragmental material, in part deposited in water. All of these clastic rocks now stand in nearly vertical positions, with a strike a little north of east.

Sharply marked off from the clastic rocks are four types of igneous rocks, hornblende-porphyrite, granite, diabase, and gabbro. The granite is divisible into two types, ordinary granite, and granite-porphyry, in both of which the ferro-magnesian constituent is almost exclusively pyroxene and the predominating feldspar anorthoclase. The origin of the granite is truly eruptive; having broken through the surrounding clastics; the rock is not formed, as held by N. H. and A. Winchell, from the recrystallization in situ of the sedimentaries of the region.

The slate formation, the green schist, and the volcanic tuff belong to the Keewatin, the Minnesota equivalent of the Lower Huronian. The conglomerate contains pebbles, many of which are similar to some of the Keewatin rocks, and it seems to belong to a newer series, although as yet no unconformity between the conglomerate and other rocks has been discovered. Following Lawson, it is believed that the conglomerate is a part of the Keewatin, probably separated from the lower part of that series by an unconformity, and that it is much older than the Animikie. However, the question whether the clastics belong to one or two series is as yet open.

The porphyrite and the granite are of Keewatin age. The porphyrite is regarded as contemporaneous with the deposition of volcanic tuff and green schist, and the granite is believed to date from the folding of the Keewatin. The age of the diabase dikes is not known; they are perhaps contemporaneous with the great diabase intrusions in the Animikie. The gabbro is of early Keweenawan age.

Grant[1] sketches the geology of the eastern end of the Mesabi iron range in Minnesota, including T. 64 N., Rs. 3 and 4 W., and parts of Rs. 2 and 5 W., with some adjacent portions of Ontario. The rocks can be separated into three divisions. The chief one of these is the Animikie series, containing the iron-bearing rocks of the Mesabi range. Older than the Animikie is a series of granites, greenstones both massive and schistose, conglomerates, slates, and other clastic rocks, called the pre-Animikie. Younger than the Animikie are some diabase sills and the great gabbro mass of northeastern Minnesota.

[1] Sketch of the geology of the eastern end of the Mesabi iron range in Minnesota, by U. S. GRANT: Engineers' Year Book, Univ. of Minn., 1898, pp. 49–62. With sketch map.

Of the pre-Animikie rocks, the greenstones and clastic rocks have been called Keewatin. As the greenstones are usually associated with the Mesabi iron-bearing rocks, these alone of the Keewatin rocks are described. They lie to the north of the iron-bearing rocks in T. 65 N., R. 5 W., and extend eastward to the center of T. 65 N., R. 4 W., where they disappear under the Animikie strata. In general, the greenstones are at present diorites; originally some were certainly diabases, others were of the nature of andesites, and a large part were diorites, or possibly gabbros. At places, especially along the east side of Sec. 27, T. 65 N., R. 5 W., the greenstones contain angular and subangular fragments of rock almost like themselves, and some may be regarded as composed of fragmental volcanic rocks. Associated with the greenstones, especially in Secs. 22, 23, and 24, T. 65 N., R. 5 W., are small masses of more acid rocks, quartz porphyries and quartzless porphyries, which are probably younger than the greenstones.

The pre-Animikie granite has its typical development on the shores of Saganaga Lake. In a number of places it may be seen in intrusive relations with the greenstone. A quarter of a mile south of the N. E. corner of Sec. 23, T. 65 N., R. 5 W., many granite dikes cutting the greenstone are seen, and on the south shore of West Seagull Lake granite dikes of the same nature as the immediately adjacent main mass of Saganaga granite are seen cutting the greenstone. Both granite and greenstone are cut by another series of finer grained, more acid granite dikes.

The Animikie rocks rest unconformably upon the pre-Animikie rocks, and usually on the southern slope of the Giant's Range, which is composed essentially of granite. The strike is approximately E N. E., and the dip in general about 10° E. of S. The thickness varies from nothing to 4000 feet. The Animikie is separable into four conformable divisions: (1) the lower or quartzite member, called the Pewabic quartzite; (2) the iron-bearing or taconyte member; (3) the black slate member; (4) the graywacke-slate member.

(1) The quartzite member is well developed in Itasca county, but disappears before reaching the eastern side of St. Louis county.

(2) The rocks of the iron-bearing member are similar to those in St. Louis county on the western end of the range, described by Spurr.[1] They differ, however, in two features. They are more completely

[1] Geol. and Nat. Hist. Surv. of Minn., Bull. X, 1894.

crystalline, and the iron is magnetite instead of hematite. The rocks consist chiefly of jaspers, amphibole (grünerite) schists, greenish siliceous slates, cherts, cherty carbonates, and magnetite slates. It is believed that these rocks were originally glauconitic green-sands; that the ore has been derived from the iron in the glauconite, and that the ore bodies result from concentration and replacement. In this part of the Mesabi range no ore bodies have yet been found which are at the same time both rich enough and large enough for profitable mining, although vast quantities of magnetite ore occur at or near the surface.

The dip of this formation varies from an average of 45° to 50° on the west to less than 15° on the east, and the thickness varies from 650 feet or less on the west to 900 feet on the east.

(3) The black slate is essentially a fine-grained, black, more or less siliceous, apparently carbonaceous slate.

(4) The graywacke-slate member is composed of black to gray slates and fine graywackes, with some flinty slates; the upper part shows coarser detrital material, and the highest beds seen are fine-grained quartzites and quartz-slates. This member is well exposed on the south shore of Loon Lake.

Associated with all of the strata of the Animikie are diabase sills, and bounding the Animikie rocks on the south is the great gabbro mass. These are igneous rocks of later date than the Animikie. Near the contact with the gabbro the Animikie rocks show marked metamorphism, and usually complete recrystallization. The gabbro varies from a nearly pure plagioclase rock to titaniferous magnetite.

The pre-Animikie rocks here described, according to the nomenclature used by the United States Geological Survey, belong to the Lower Huronian series of the Algonkian system, and probably also in part to the older Archean or Basement Complex; the Animikie is regarded as the equivalent of the Upper Huronian series of the Algonkian, and the gabbro as the lower part of the Keweenawan series of the Algonkian.

Winchell, Alexander,[1] gives a detailed petrographical description of the Koochiching granite occurring on the north boundary of Minnesota, about two miles west of Rainy Lake. The rock is a biotite-hornblende granite of eruptive origin, and is assigned to the Laurentian.

[1] The Koochiching Granite, by ALEXANDER WINCHELL: Am. Geol., Vol. XX, 1897, pp. 293–299.

Coleman makes notes on the petrology of Ontario, including the Port Coldwell, Missanabie, and Wahnapitae areas.[1]

Coleman makes a third report on the gold region of western Ontario.[2]

The districts visited and here reported upon are the Upper Seine district, the Shoal Lake district, the Manitou district, the country crossed between Manitou Lake and the Lake of the Woods, the Lake of the Woods district, the West Shoal Lake district, the neighborhood of Rat Portage, and the vicinity of Fort William on Lake Superior. As in previous reports, the general geology worked out by Lawson for the Lake of the Woods and Rainy Lake districts is accepted, and the general principles applied to other districts of the region visited.

In previous years it has been held that gold was to be looked for only in the Huronian. During the past three years, however, it has been found that some of the most promising gold deposits occur in the granite or gneiss. It has also been found that the best veins, or other ore deposits, occur at or near the contact of the Laurentian eruptive rocks and the Huronian.

In the Ontario region the gold deposits occur in the following ways. (1) True fissure veins, commonly found in the areas of massive eruptive granite. (2) Lenticular or bedded veins, confined to the schistose rocks. These are intercalated between the schists and run parallel with their strike, and are not so continuous as the fissure veins. (3) Contact deposits, between the Huronian and Laurentian. These are rare in this district. (4) Fahlbands of schists, impregnated with pyrites and other sulphides. (5) In quartz, associated with dikes of porphyry or felsite, near the contact of the Huronian and Laurentian rocks, penetrating the schists, and sometimes the granite itself. (6) In an eruptive mass, in but one locality. (7) Placer deposits.

Coleman[3] gives an interesting general account of the clastic Huronian rocks of Western Ontario, in the region extending from the Lake of the Woods in the west to Lac des Mille Lacs on the east, a

[1] Notes on the petrology of Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1898, pp. 145–150.

[2] Third report on the west Ontario gold region, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VI, 1897, pp. 71–124.

[3] Clastic Huronian rocks of Western Ontario, by A. P. COLEMAN: Rept. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 151–160. Published also in Bull. G. S. A. Vol. IX, 1898, pp. 223–238.

distance of 200 miles, with a width north of Rainy Lake of 120 miles. The Huronian, including the Keewatin and Couchiching rocks, is in general an immense series of water-worn sediments, in the upper part mixed with eruptives, perhaps largely later injections, but partly pyroclastic. The Keewatin is largely of eruptive origin, though it contains important sedimentary members: the Couchiching is entirely sedimentary.

The Keewatin, and in the southern part of the region the underlying Couchiching, form sharp synclines, curving as wide meshes around the areas of Laurentian, which vary from less than a mile to fifty miles in diameter.

Diabase and porphyry eruptives form an important part of the Keewatin. These are in large part surface flows, represented by ash rocks, agglomerates, etc., but many of them are probably laccolitic sills. The water-formed clastics of the Keewatin, include limestones, slates, quartzites, grits, graywackes, breccias, and pebble and bowlder conglomerates. The limestones are of limited extent, being found in any thickness only at Steep Rock Lake. The slate on analysis yields 7.44 per cent. of carbon, pointing perhaps to the presence of life. The conglomerates are in places schistose. Near Shoal Lake the most common pebbles are quartz-porphyry and porphyrite, felsite, and green schists indistinguishable from the adjoining Keewatin schists; black and red quartzite, white pulverulent sandstone, vein quartz, and anorthosite. No gneiss or granite pebbles have been found. Most of these pebbles are easily matched by Keewatin rocks, sometimes, however, many miles distant; a few are evidently Couchiching; and none are Laurentian.

The break represented by this conglomerate comes high up in the Keewatin, instead of at its base, just above the Couchiching, as held by Lawson. Striking evidence that the break is not at the base of the Keewatin is found at Shoal Lake, where a few bowlders of the coarse-grained anorthosite found in the schist-conglomerate are exactly like portions of a boss of anorthosite two miles away. As this anorthosite area contains masses and strips of characteristic Keewatin schist, swept off during its eruption, it is evident that an immense lapse of time separates the conglomerate and the underlying Keewatin. It is probable that the conglomerates represent an important interval of erosion, perhaps equivalent to the one shown by Van Hise and others between the Upper and Lower Huronian in the states to the south.

The Couchiching rocks are all formed of clay sand, more or less metamorphosed; in general they are biotite-schists or gneisses, the quartz showing a clastic origin. The Couchiching passes up by transiion into the Keewatin, and there is no reason why the two together hould not be classed as Huronian.

Following Lawson's estimate, the Keewatin and Couchiching series ogether sum up 50,000 feet in thickness.

The term Laurentian is employed, as Lawson and other Canadian eologists are accustomed to employ it—in a petrographical and tructural sense—for crystalline gneisses and granites underlying the Huronian, although it is evident that these rocks have consolidated at time later than the Huronian.

As described by Lawson, the Laurentian (Lower Archean) "occurs n large isolated central areas, more or less completely surrounded by he schists of the upper Archean, the encircling belts anastomosing nd forming a continuous mesh work." It consists chiefly of a coarse eddish, often porphyritic rock, usually granite in the central part of he area, but showing a foliation, generally parallel to the periphery, here it comes in contact with the Huronian.

Throughout the region the Laurentian is in eruptive contact with he Huronian, and nowhere is a basal conglomerate of the Huronian ound. Near the contact with the Huronian, strips and fragments of he Huronian are embedded in the gneiss; also dikes of granite, pegnatite or felsite generally run from the gneiss into the Huronian. The rger areas of gneiss and granite are evidently batholites. Some of the maller granite bosses may be stumps of old volcanoes. The Huronian chists usually dip rather steeply away from the gneiss, at an angle eldom less than 45°. Finer-grained granites cut both the Keewatin nd the Laurentian. However, it is not easy to say whether a given ranite is Laurentian or a later granite.

It is believed that as a result of the piling up of a thickness of eight ten miles of sediments and eruptive materials, represented by the eewatin and Couchiching rocks, the slowly rising isogeotherms softed or fused the foundation, which rose into domes, the inner parts lidifying as granite, and the outer, more viscid portions having their nstituents dragged into rough parallelism with the adjoining solid cks and forming gneiss.

As the Huronian rocks south of Lake Superior and in New Brunsck are described by Van Hise and Dawson as presenting basal con-

glomerates resting unconformably on the Laurentian, it is suggested that in these cases the thickness of the sediments was not great enough to depress the Laurentian floor to the level of fusion or plasticity; or, that the Huronian, as recognized in these regions, is really younger and overlies the upturned edges of the rocks described as Huronian in the northern Archean.

Comments.—The above discussion is based on the most thorough field work yet done in this area, and the account probably marks an advance in the interpretation of the pre-Cambrian stratigraphy of the area northwest of Lake Superior, although the conclusions cannot yet be accepted as final. Some of the conclusions differ from those o other workers in this area, and such may be especially noted.

The Couchiching is believed to be entirely a sedimentary series conformably below the Keewatin, and in eruptive contact with the Laurentian granite and gneiss below. Lawson regarded the Couchiching as sedimentary, but believed that there was an unconformity between it and the Keewatin, because of the great differences in the characters of the materials, the degree of crystallization, and the presence of basal conglomerates in places at the base of the Keewatin Coleman has previously accepted these conclusions. Van Hise accepting Lawson's conclusion as to the position of the Couchiching below the Keewatin, supposed the Couchiching to belong to the Basement Complex or Archean. However, recent personal work in the fiel has led him to the conclusion that the Couchiching of Rainy Lake largely a sedimentary series, which is equivalent in age to the upp part of the series mapped by Lawson as Keewatin in the same area.

The insistence on the eruptive contact of all the rocks of the La rentian with the Huronian and the explanation of the origin of tl Laurentian may also be noted. Coleman believes that the gneiss and granites of the Fundamental Complex do not represent the eartl *erstarrungskruste*, but are portions of the earth's crust, of sedimenta or other origin, which have been buried deeply enough for hydı thermal fusion, and have afterwards been disinterred by long-continu denudation. After fusion of course such rocks would be really erupti and of later age than the Huronian rocks above, even though origina they may have been older than them and formed the floor upon whi the Huronian rocks were deposited. This is essentially the positi of Lawson. Van Hise, on the other hand, believes that here t granites and gneisses heretofore included under the Laurentian of tl

gion may be separated into (1) a granite-gneiss basal complex, form-
g the basement upon which the Huronian was deposited, and perhaps
presenting a portion of the original crust of the earth or its down-
rd continuation, and (2) later granite and gneiss intrusive in the
uronian, and therefore of Huronian or post-Huronian age. This
scrimination has been uniformly made south of Lake Superior, in a
mber of cases in Canada, and in other parts of North America, and
is believed that it may also be made in this region of western Ontario.
this were done the rocks of the true fundamental complex in this
ea would occupy perhaps a very small area. Whether such a com-
ex may be called Archean, as advocated by the United States geolo-
sts, or by some other name, is immaterial. If the term Laurentian
employed, it would need to be redefined to cover the narrower range
rocks, and because of its present wide application, including both
e basal complex and later eruptives, some confusion might result.
e term Archean has been carefully defined and consistently used
the United States geologists to represent the oldest group of rocks
basal complex, and in this narrow application has priority to any
her term.

The portion of the granites and gneiss intrusive in the Huronian
uld be called simply Huronian or post-Huronian. If the true basal
mplex be altogether absent in this region, the granites and gneisses
w called Laurentian are of Huronian or post-Huronian age, and are
t to be correlated with rocks of the true basal complex of other areas.

Parks[1] describes the geology of the base and meridian lines in the
iny River district, in an area extending from Lac Seul on the north-
st and Lake Wabigoon on the southwest, to Sturgeon Lake and Mat-
ra Lake on the east. Laurentian and Huronian rocks occur in folds
h a general northeast-southwest trend. The Huronian rocks occur
three main areas, the Sturgeon River area, the Lake Minnetakie area,
l the Wabigoon Lake area. They consist of altered traps, horn-
nde-schists and other green schists, altered porphyrites, quartz
phyries, phyllites, and conglomerates. In general they resemble
wson's Keewatin series to the south. The Laurentian consists of
nblende-syenite, hornblende-granite-gneiss, mica-syenite, biotite-
nite-gneiss, and various granitic rocks. C. K. LEITH.

[1] Geology of base and meridian lines in the Rainy River district, by W. A. PARKS:
. Bureau of Mines, Ontario, Vol. VII, 1898, pp. 161–183. With geological map.

REVIEWS

Report on the Building and Decorative Stones of Maryland. GEORGE P. MERRILL and EDWARD B. MATHEWS. Part Vol. II, Geol. Survey of Maryland.

The first 75 pages of the Building Stone Report of the Maryla Geological Survey are written by George P. Merrill, and compris discussion of the physical, chemical, and economic properties of bui ing stones. The following 116 pages are written by Edward B. Mathe and are an account of the character and distribution of Maryland bui ing stone.

In the first part Merrill classifies the rocks of Maryland, which available for constructive and ornamental purposes, into (1) gran and gneisses; (2) common limestones and dolomites; (3) the marl (crystalline limestones and dolomites); (4) sandstones and conglon ates; and (5) the argyllites and slates. The three great classes rocks, eruptive, clastic sedimentary, and metamorphic; the diver of the geological resources of Maryland; the method of format present position, and the conditions under which the sedimentary igneous rocks formed; and the way in which mountain-buil forces have since modified them, are successively discussed.

The author explains how several grades, and often kinds, of s mentary rocks may occur in a single quarry. The effect which position of the strata, horizontal or tilted, has upon the cost of q rying; the size and shape of the blocks resulting from jointing bedding; the manner in which river erosion, weathering, and gla influence the accessibility of the stone in the quarry; and the leading nature of dry seams and superficial induration, are cl explained.

Following a discussion of the general distribution of Mary building stones in reference to the physiographic regions of the s Merrill considers the methods of quarrying and the more impo kinds of machinery now employed. The important part which petition plays in the development of the stone industry has led

brief discussion of the quarrying industry of each of the Atlantic coast states. In this the author briefly describes the kinds of rocks quarried and reviews the character of the output and the facilities for successful development. It is concluded from these observations that the future of the quarrying industry of Maryland must depend not so much upon the kinds of materials as upon the ability to compete in prices.

After treating the subject of weathering in general, Merrill refers more particularly to the effects of alternating temperatures and the freezing of included water. The danger of laying stone on edge, on account of the freezing of water which may collect along the sedimentary planes, as well as the results of water freezing in the pores of the rock, are emphasized. In this connection the author concludes that "other things being equal, a stone possessing low absorptive power will be more durable . . . . than one that will absorb a large amount;" "granites and gneisses, possessing low ratios of absorption, and being made up so largely of silica and silicate minerals, are very little affected by freezing and solution;" and that "a ratio of absorption of more than 4 per cent. by weight (in sandstones) must be regarded as unfavorable."

In a discussion of the physical tests Merrill describes in an interesting manner the more important methods employed by different experimenters in performing the various durability and strength tests. In the discussion of the freezing and thawing tests the observation is made that "the results obtained on coarse and fine varieties of Portland sandstone suggest at least that water would freeze out of coarse stone, and therefore create less havoc than in those of finer grain." In the discussion of the specific gravity the conclusion is reached that "of two stones having the same mineral nature, the one having the highest specific gravity, that is, the greatest weight bulk for bulk, will be the least absorptive, and hence, as a rule, the most durable." The method suggested for determining the weight per cubic foot of stone is to multiply the weight of a cubic foot of water by the specific gravity of the stone. The method suggested for obtaining the absorptiveness of the rock is the one commonly employed, of soaking the sample in water for three or four days and determining the percentage gained in weight thereby.

In speaking of the crushing strength of stones, the author believes that to continue making these tests is unnecessary, except in "extreme cases."

Since the first of the century the quarrying industry of Maryland has received attention incidentally from many different students of geology. The various publications which have resulted from these studies are summarized by Mathews in the first pages of the second part of the report. Mathews considers the more important quarry areas under the heads of (1) granite and gneiss; (2) marbles, serpentines, and limestones; (3) quartzite and sandstones; and (4) slates and flags. This classification is somewhat different from that followed by Merrill in the first part of the report.

In the treatment of each area the author gives a brief historical sketch of the development of the industry, and a discussion of the rocks as they occur in the quarry. In some instances the microscopical and chemical analyses are given, and also the results of physical tests, including a determination of the crushing strength, ratio of absorption, specific gravity, and weight per cubic foot. The rock as it occurs in the quarries and natural exposures; the mineralogical composition and texture; and the colors of the granite, limestone, marble. serpentine, and sandstone, are well illustrated by cuts, photomicrographs, and colored lithographic plates.

The granites of Maryland are shown to be ordinarily schistose, and mainly of a gray color. The granite from one or two of the quarries is described as having a reddish or pinkish color, but possessing a porphyritic texture. In the case of the rock known as gneiss, occurring in the vicinity of Baltimore, the color and texture vary with the alternation of layers. In all cases the dimensions are controlled by jointing planes, which strike in various directions, owing to which the stone can often be used only for the smaller constructional purposes.

The marbles and limestones of Maryland are the most widely distributed of all the building stones, and occur in most of the formations from the Algonkian to the Triassic. The Cockeysville marble is exploited the most largely, and is probably the best known of Maryland limestones or marbles. The Potomac marble is a conglomerate with a striking color and texture, and is the only stone of this character used to any extent in the United States.

Serpentine has been quarried in several places, mainly for decorative purposes. Dry seams have seriously interfered with the successful development of this stone, and the quarries have been temporarily abandoned.

Sandstone is quarried extensively in only one locality, Seneca. The

best stone in the quarries is interstratified with beds of unsalable material, which naturally interfere with the economy of working.

Slate has been quarried in two different areas in Maryland, known as the Peach Bottom district and Ijamsville. The former district is the only one in which quarrying is now actively carried on. From this district a good quality of slate is obtained. The output has shown a slight decrease since 1894, when it reached its maximum importance.

E. R. BUCKLEY.

Fifteenth Annual Report of the State Geologist (*New York*) *for the Year 1895*, Vol. I. JAMES HALL, State Geologist, Albany, 1898.

THIS report, published in a ponderous volume of 738 pages with broad margins, large type and heavy paper, is particularly unwieldy, and would be far more convenient for the student were it issued in a size and form conformable with the preceding reports of the survey. It is particularly aggravating to the librarian to have a continuous series of reports which should be kept together upon his shelves vary so greatly in size. The 1894 report and those preceding it are convenient sized octavo volumes, while this 1895 report is a great book standing fourteen inches high, although the matter contained, page for page, is about equivalent to that in the earlier reports. The edition of the report, issued as a part of the regents' report of the New York State Museum, is printed upon thinner paper, and has the margins trimmed down so that it is a more convenient size, but even that is considerably larger than the preceding reports of the survey.

The criticism upon the style of publication, however, cannot be extended to the contents of the volume as each one of the papers communicated is a valuable addition to the literature of New York geology, and many of them are of more than local interest. Each of the papers will be briefly noticed, much of what follows being taken from the "Synopsis of Results" by the state geologist upon pages 11–26 of the report.

Two paleontologic papers, both by James Hall, (1) "A Discussion of Streptelasma and Allied Genera of Rugosa Corals," and (2) "The Paleozoic Hexactinellid Sponges Constituting the Family Dictyospongidæ," are announced in the synopsis of the report but do not appear. However, since this volume is marked Volume I on the title-

page, it is possible that another part containing these papers is contemplated.

1. *The Stratigraphic and Faunal Relations of the Oneonta Sandstones and Shales, the Ithaca and Portage Groups in Central New York.* By J. M. CLARKE. Pp. 27–81, plates I–VII and two maps. "This report presents a revision and summary of observations previously made by the same author with reference to the position of the Oneonta sandstones and their extent westward from the Chenango River, and adds thereto more recent data bearing upon the passage of the Ithaca fauna in the region of its highest development in Cortland and western Chenango counties into the typical fauna of the Portage group."

"The *Portage group* is a series of arenaceous deposits representing the geological time which elapsed from the close of the Hamilton period (including the Tully limestone and a portion of the Genesee slate when present) to the opening of the Chemung period. The typical and unmixed fauna of its westerly sections has little organic relation to the proper fauna of the Hamilton shales, the Chemung fauna succeeding, or the Ithaca faunas adjoining on the east. It is an exotic fauna, evidently derived from the west and making its first appearance in the Genundewah limestone of the Genesee slates. It is the *Naples fauna.*"

"The fauna of the central and east-central sections is an indigenous fauna, and its organic composition stands in the closest relation to the fauna of the Hamilton group, but in its later manifestations assumes many characters of the Chemung fauna. In the Chenango Valley and eastward the upper portion of the deposits of this age is represented by the Oneonta group with a very sparse fauna and well-characterized strata. In Chenango county they replace the higher beds bearing the Ithaca fauna."

2. *The Classification and Distribution of the Hamilton and Chemung Series of Central and Eastern New York.* By C. S. PROSSER. Pp. 83–222, plates I–XIII and one map. The investigations described in this report were undertaken in order to trace the boundaries of the Oneonta group of sandstones and shales and to elucidate as far as possible the division line between the Hamilton group and the overlying strata. This latter is a perplexing problem because east of the Chenango River the Tully limestone and Genesee slate are wanting and the sandy shales of the Hamilton group pass upward into those of the Ithaca group with slight lithologic changes and with alterations o

the fauna so gradual as to be perceptible only upon very careful observation. It is shown that the more or less barren Sherburne sandstones separate the faunas of the Hamilton and Ithaca groups, and represents the beds which have been designated as Lower Portage in western New York. The correctness of this correlation is shown by the discovery of the typical Tully limestone species *Hypothyris venustula* = *H. cuboides* just below the Sherburne sandstone near Noblesville in Otsego county very much farther east than this species has been previously found.

The results of Prosser's investigation necessitate the changing of the upper boundary of the Hamilton formations from five to fifteen miles further south than the similar line on the geologic map recently published by the Geological Survey of New York.

3. *The Stratigraphic Position of the Portage Sandstones in the Naples Valley and the Adjoining Region.* By D. D. LUTHER. Pp. 223–236, plates I–II and one map. The purpose of the investigation described in this paper was to ascertain the dividing line between the Portage and the overlying Chemung group in western New York. The section of the Portage series in the Naples Valley is described in detail, and the Portage sandstone which marks the upper limits of the series is shown to lie at an elevation of 600 feet above the base of the series. With the data derived from the study of the Naples section the Portage sandstone is traced eastward to Seneca Lake and westward to Lake Erie.

4. *The Economic Geology of Onondaga County, New York.* By D. D. LUTHER. Pp. 237–303, plates I–XXI and one map. In this paper the rock formations of the county, from the Clinton group below to the Portage shales above, are discussed in their proper order of succession. While attention is given to the geologic character and distribution of each formation, the especial value of the report consists in its exhaustive treatment of the most important economic products of the county, viz., salt, soda-ash, gypsum, hydraulic cement and quarry stone.

5. *The Structural and Economic Geology of Erie County.* By I. P. BISHOP. Pp. 305–392, plates I–XVI, figures 1–6. This paper opens with a brief account of the topography of the region, after which the stratigraphic succession is discussed at considerable length. The formations present extend from the Salina group at the bottom to the Portage group at the top. The superficial deposits are discussed under

the head, "Quaternary Geology." The economic products of the county which are discussed are building stone, hydraulic cement rock, clays, sand, gravel and natural gas. In connection with the discussion of these products many valuable statistics are given and a considerable amount of space is devoted to the records of wells which have been sunk for natural gas in and about Buffalo.

6. *Geology of Orange County.* By H. RIES. Pp. 393–475, plates I–XLII, with one geological map. In this report the physiography and topography and the stratigraphic, structural and economic geology are ably discussed in detail. The formations present extend from the pre-Cambrian gneiss at the base of the section to the Chemung group at the summit. The economic products described are road materials, brick clays, limestone, lead ore, building stone, flagstone, and iron ores, besides the soils, mineral springs, water power and water supply.

7. *Report on the Crystalline Rocks of St. Lawrence County.* By C. H. SMYTH, JR. Pp. 477–497. The principal purpose of the investigation described in this paper was to determine the distribution of the crystalline limestones, and to collect data bearing upon the question of the origin of the gneisses and the relation existing between these rocks and the limestones.

8. *Report on the Geology of Clinton County.* By H. P. CUSHING. Pp. 499–573, plates I–V. This paper discusses the topography and general geology of the region, after which each township is treated separately. The rock series discussed are, (1) gneissic series; (2) limestone series; (3) gabbro series; (4) Paleozoic series, extending from the Potsdam sandstone to the Utica slate; (5) dike series; (6) pleistocene deposits.

9. *Preliminary Report on the Geology of Essex County.* By J. F. KEMP. Pp. 575–614, plates I–XII. This is a continuation of the report by the same author in the 1893 report, and the townships not previously described are taken up for special consideration and the areal geology of each is described so far as it has been determined. Special notice is taken of economic products, namely, of iron ores.

10. *Sections and Thickness of the Lower Silurian Formations on West Canada Creek and in the Mohawk Valley.* By C. S. PROSSER and E. R. CUMMINGS. Pp. 615–659, plates I–XII. The writers here consider the Ordovician rock sections exposed in the gorge of the West Canada Creek at Trenton Falls, at Newport and at Little Falls. These

sections have all been previously studied by other observers, some of them frequently, and not always with concordant results. In this paper, both measurements of thickness, and identification of species of fossils have been made with care, and while the conclusions are not in complete harmony with already expressed opinions, they doubtless afford a more precise knowledge of the formations considered.

11. *Report on the Talc Industry of St. Lawrence County.* By C. H. SMITH, JR. Pp. 661–671.

12. *Physical Tests of the Devonian Shales of New York State to Determine their Value for the Manufacture of Clay Products.* By H. RIES. Pp. 673–698. This paper is introduced by a brief discussion of the general, chemical and physical properties of shales. This is followed by some notes upon the manufacture of paving brick and the requisite qualities of such brick. The remaining pages are devoted to a discussion of the extent of the New York shales with tests of samples from typical localities.

13. *The Discovery of Sessile Conularia.* By R. RUEDEMANN. Pp. 699–728, plates I–IV. This important paper is based upon the study of some obscure organisms found in the Utica slate at Dolgeville, N. Y. As a result of the study much light is thrown upon the nature and mode of development of this widespread but little understood organism, *Conularia*, in regard to whose taxonomic position there has been a widely diverse expression of opinion. *Conularia* has usually been referred to the Pteropods, but the results of the investigation recorded in this paper seem to indicate that it should be placed with the Cephalopods.

14. *Notes on Some Crustaceans from the Chemung Group of New York.* By J. M. CLARKE. Pp. 731–738. In this paper are discussed two crustaceans from the Chemung group, (1) *Pephricaris horripilata*, a peculiar, highly ornamented Phyllocarid crustacean, and (2) *Bronteus senescens*, one of the very few trilobites of this formation.

STUART WELLER.

Iron Making in Alabama. By W. B. PHILLIPS. Alabama Geol. Surv., Second Ed., 380 pp. 1898.

It is not often that a state survey finds it necessary to issue a second edition of any of its reports, and the fact that Dr. Phillip's well-known report now appears in new form is a well deserved compliment

to both the author and the enterprising Survey of Alabama. It is more than that; it is a very notable indication of the rapid progress which Alabama is making in iron making. An examination of the report shows this progress strikingly. Over a hundred pages of new matter have been added and chapters on Coal and Coal Washing, Concentration of Low-Grade Ores and Basic Steel and Basic Iron, indicate the lines of progress. The first edition of the report was intended for a general treatment from the point of view of raw materials. The new edition, by the addition of much valuable matter, has become as well almost a manual on iron making from low grade ores and is accordingly of much wider usefulness. In bringing together widely separated technical papers and adding to the material so much from the results of his own laboratory, Dr. Phillips has placed all interested in the subject in his debt. It is unfortunate that so good a report should be presented in such poor form. The paper, press work, and proof reading leave much to be desired.

H. FOSTER BAIN.

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ERRATUM

On page 38, eleven lines from the top, instead of "*are frequently fo one foot*," read "*are sometimes found one-half mile.*"

THE

JOURNAL OF GEOLOGY

APRIL–MAY, 1899

THE VARIATION OF GLACIERS. IV[1]

The following is a summary of the third annual report of the International Committee on Glaciers.[2]

RECORD OF GLACIERS FOR 1897

Swiss Alps.—The glaciers of this region are in general in a state of retreat. Of fifty-six glaciers observed, thirty-nine are retreating; five are stationary; twelve are advancing.

Two glaciers have been under observation during a complete period, the Zigiorenove and the Trient. The Zigiorenove had a maximum in 1852; it retreated from then until 1878 (twenty-six years); it then advanced until 1896 (eighteen years), when it had another maximum. Hence its entire period from maximum to maximum amounted to forty-four years.

The Trient had a maximum in 1845; from that time it

[1] The first three articles of this series appeared in this JOURNAL, Vol. III, pp. 278–288; Vol. V, pp. 378–383, and Vol. VI, pp. 473–476.

[2] Archives des sciences phys. et nat., Vol. VI, pp. 52–84, Geneva, 1898. At the meeting of the International Committee on Glaciers, in St. Petersburg, on September 1, 1897, Professor Ed. Richter was elected president, and Professor Finsterwalder, secretary, for the following three years. The following investigators were elected corresponding members of the committee: Professor Torquato Taramelli, Pavia; Dr. Thoroddsen, Reykiavik, Iceland; Baron Gerard de Geer, Stockholm; Constantin Rossikow, Wladikavkas; Professor Dr. Sapojnikow, Tomsk; Dr. A. Hamberg, Stockholm; M. Lipski, St. Petersburg; Professor Israel C. Russell, Ann Arbor, Mich.; M. I. Coaz, Bern; M. Chas. Rabot, Paris.

retreated until 1878 (thirty-three years); it then advanced until 1896 (eighteen years), when it had another maximum, which makes its entire period fifty-one years.

There remain still among the Swiss glaciers some marks of the increase of the last quarter of the nineteenth century, but the retreat of the glaciers is now, very generally, in full force.[1]

Eastern Alps.—The important results obtained during the current year in the eastern Alps justify the labor undertaken to obtain them. It has been shown that the partial advance observed since 1885 extends towards the east beyond the Brenner, even as far as the groups of the Venediger and the Glockner; and it is most probable that this is not the result of the great precipitation during the past two years, but is due to some more general cause; for it has been possible to predict it in the case of the Gliederferner since 1892. This same glacier has also given us some information in answer to the question—does the swelling of a glacier move down the glacier more rapidly than the rate of flow of the ice? The reply is affirmative. From 1887 to 1892 the ice had moved a distance of 110 meters, whereas the swelling had advanced 250 meters. When the swelling reached the point at which the velocity was measured, it produced a considerable increase in the velocity of the ice. Similar results are also found with the Vernagtferner.

Of these glaciers we have, definitely, twenty-six advancing, eight stationary, and twenty-six retreating. The retreat seems to be more general as we go further eastward.[2]

Italian Alps.—No results are given for these glaciers, but a careful report is made of the means taken for marking their positions, so that in the future the variations of a large number may be determined.

Scandinavian Alps.—So far as observations go, the glaciers in this region are either stationary or retreating.[3]

[1] F. A. FOREL, XVII Rapport sur les variations periodiques des glaciers des Alpes suisses. Jahrbuch des Schw. Alpenclubs, Vol. XXXIII, p. 249. Bern, 1898.

[2] Report of PROFESSOR FINSTERWALDER.

[3] Reports of DR. SVENONIUS and DR. OYEN.

Spitzbergen.—The most important work on these islands is hat of Baron de Geer, who has visited them several times. He nds from the maps and photographs that the glacier of Seftröm has advanced about four kilometers since 1882, but at resent seems to be retreating. On the other hand, the glacier f von Post has retreated slightly since 1882 Sir Martin Conway found that the glacier, which he called the Ivory Gate, has dvanced very considerably since 1870. The best accounts of he observations of Sir Martin Conway's party are found in the *Geographical Journal*, April 1897, and in the *Quarterly Journal of Geology*, 1898, Vol. LIV, pp. 197–227.

Dr. A. Hamberg has written on the parallel structure of glaciers. He thinks that this, as well as the similar structure bserved in Antarctic ice, is due to stratification.[1] He thinks, lso, that the movement of these glaciers is due to the slipping f successive layers over each other, and that there is practically o differential movement in the layers themselves. Dr. Hamberg thinks that in these latitudes greater pressure is necessary o convert the névé into solid ice than in warmer climates, and e thus explains the fact that many of these glaciers are not ery thoroughly consolidated.

Franz Josef Land.—Dr. Nansen tells us, in the account of is celebrated polar expedition, that there are no true glaciers n these islands, but that they are covered with masses of ice loping toward the sea. These are apparently of the same type s those described by Dr. Hamberg. Dr. Nansen also tells us hat he found indications of the existence of a former glacier all ong the northern coast of Siberia. He also gives us interestg descriptions of the folding and crushing of the polar ice as a sult of ocean currents.[2]

Greenland.—A Danish expedition visited the island of Disco 1897 and examined the glaciers of Blösedalen, which had en visited in 1894 by Professor Chamberlin. They found that

[1] REV. O. FISHER gave the same explanation of the horizontal markings in Antic ice. Phil. Mag. (5) 1879, Vol. VII, pp. 381–393.

[2] Report of PROFESSOR NATHORST.

the two southern glaciers on the western side of the valley have made a marked retreat in the interval, and they established stations for the future observations of these glaciers.[1]

Caucasus.—In this region a very large number of glaciers have been examined and photographed. They show a marked state of retreat.

Turkestan.—Twenty-six glaciers have lately been discovered and described by Dr. Ivanow in the mountain chain of Talassk Alataou. They all have a great altitude and show indication of such a great retreat that they may perhaps disappear altogether. Many new glaciers have been examined and photographed in the mountain chain of Peter the Great. They are apparently in a marked state of retreat.

The Altai.—Professor Sapojnikow has discovered in the last few years five glacier centers in the Altaï mountain. These contain more than thirty glaciers, some of which compare in size with the largest glaciers of the Caucasus. All of them are evidently retreating, but it is not yet possible to give even an approximation to the rate.[2]

A very interesting and full account of our present knowledge of Arctic glaciers and their variations has been published by M. Charles Rabot, under the imprint of the International Committee on Glaciers.[3] After a short account of the characteristics of Arctic glaciers he takes up in detail various glaciers, with references to original sources of information, with the following results:

The glaciers of Grinnell Land appear to have attained a maximum shortly before 1883.

The inland ice of Greenland seems at present to be at a maximum, particularly in the north. In the south a slight retreat is showing itself but too slight to arrest the general advance of the ice which has been going on during the historic period.

[1] Report of Dr. STEENSTRUP. Dr. STEENSTRUP went back to Greenland in May 1898 to continue the study of the glaciers there, which he discontinued in 1880.

[2] Report of PROFESSOR MOUCHKETOW.

[3] Les variations de Longueur des Glaciers dans les Regions Arctiques et Boreales. Archiv. des Sciences phys. et nat. Geneva, 1897, Vol. III.

The glaciers of Iceland began to advance at the end of the seventeenth century, at which time they were much smaller than at present. This advance continued, interrupted about the middle of the eighteenth century by a hesitating retreat in the case of certain glaciers. After this, most of the glaciers made an extraordinary advance; a veritable invasion of the ice took place, which continued during the larger part of the nineteenth century. After this advance there was a general retreat, though some glaciers are still advancing. The retreat began earlier in the north (1855 to 1860) than in the south (1880). It is less marked than the preceding advance.

There is a large volcano on Jan Mayen Land on which are nine large glaciers. A study of the records of whalers and explorers seems to show that these glaciers have advanced since the end of the seventeenth century.

REPORT ON THE GLACIERS OF THE UNITED STATES FOR 1898[1]

The end of the Eliot glacier on Mount Hood, Oregon, is supported by its lateral moraines, and is much covered with débris. On each side, one or two hundred yards from the end, the ice seems to be breaking through these moraines. This may be due to stream erosion, washing out the moraines and thus removing the support for the ice; or it may mean the beginning of an advance (*H. D. Langille*).

Professor Russell has recently published a most interesting account of the glaciers of Mount Rainier.[2] He describes the characteristics of a system of glaciers on a conical peak. Starting in general from a common névé region the glaciers separate into distinct streams lying in deep channels. The V-shaped intervals between them are occupied by smaller glaciers, which he has called inter-glaciers. He thinks the amphitheaters at the

[1] The synopsis of this report will appear in the Fourth Annual Report of the International Committee. The report on glaciers of the United States for 1897 was given in this JOURNAL, Vol. VI, pp. 475, 476.

[2] The Glaciers of Mount Rainier, Eighteenth Annual Report of the U. S. Geol. Surv., pp. 349–423. A preliminary note on PROFESSOR RUSSELL'S observations appeared in Variations of Glaciers, II.

head of some of the glaciers are the result of glacial erosion; he gives also an interesting account of dome-shaped elevations, much broken with crevasses, which seem to be a peculiarity of these glaciers; they are apparently due to elevations in the bed of the glacier. Professor Russell describes all the glaciers except those on the western side of the mountain. He finds them all very much covered with débris at their lower ends, and notes that there is a general retreat. At one point he noticed that the surface of the Cowlitz glacier, about two miles from its lower end, has recently been lowered seventy-five to a hundred feet, as indicated by fresh lateral moraines deposited on the mountain. The Carbon glacier has receded about one hundred yards between 1881 and 1896, and the Willis glacier about five hundred feet in the same interval. All the other glaciers show a marked diminution, but the amounts were not determined.

Professor Russell has kindly sent me the following account of the glaciers in the state of Washington, which he saw in 1898. It will be noticed that their number is far greater than had been supposed.

Glaciers on the Wenatchee Mountains.—In examining the records of the old glaciers of the state of Washington it was found that the Wenatchee Mountains formed an independent center of ice dispersion from which flowed several large glaciers. One is not surprised, therefore, to find small glaciers still lingering on the higher portions of this rugged and exceedingly picturesque group of granite peaks.

On the summit portion of the Wenatchee Mountains about four miles due east of the culminating pinnacle of Mt. Stuart, there is a glacier measuring by estimate one mile from north to south, including both névé and true glacial ice, and of somewhat less width. It lies on the highest portion of the western rim of a magnificent amphitheater excavated in compact granite. A view into this desolate but wonderfully attractive basin, from the narrow crest forming its eastern wall, is the finest and most instructive picture of its kind to be found in the entire Cascade region.

On the north side of Mt. Stuart, about one thousand feet below its summit, which rises 9470 feet above the sea, there are three small glaciers, situated in steep gorges or clefts in the granite, and sheltered by outstanding cliffs; combined, they would probably make an ice body less in mass than the one described above. These glaciers are narrow, and extend down the gorges where they occur for some two thousand feet. Below each there is a small and fresh-looking moraine.

The glaciers just described derive their main interest from the fact that they are isolated, being some twenty-five or thirty miles to the east of the main divide of the Cascade Mountains.

Glaciers on the Cascade Mountains.—The glaciers of the Cascade Mountains south of the United States-Canadian boundary probably number several hundred, and of these about 100 or 150 have been seen by the writer; but only a few, in the immediate vicinity of Glacier Peak, have actually been traversed. All of them are small; of those seen, probably the largest is not over two miles in length, and by far the greater number are considerably below this measure. Nearly all lie in amphitheaters or cirques. Their principal interest centers in their distribution, their relation to climatic conditions, and the fact that all of those seen are accompanied by evidences of recent recession.

There is one small glacier, however, that is worthy of special study in reference to the manner in which an ice-stream expands when not confined by walls of rock, and in expanding, forms longitudinal, or perhaps more properly, radial crevasses in its fan-shaped terminus. The glacier referred to is at the head of White Chuck Creek at the immediate south base of Glacier Peak, but on the south side of the deep canyon in which flows the branch of the creek nearest to the base of the peak. This glacier flows northward, and is in full view from Glacier Peak. The periphery of its broadly expanded extremity is not over 1000 or 1500 feet by estimate, and is broken by some four or five radial crevasses which are widest on the outer margin of the fan-shaped expansion and contract to narrow clefts which become still smaller, and disappear when traced toward the feeding névé.

This is a typical miniature example of glaciers like the Rhone glacier, Switzerland, and the Davidson glacier, Alaska.

Most of the glaciers on the Cascades have a lower limit of about six thousand feet; the majority of them are west of the Cascade divide, and are either in immediate proximity to or on Glacier Peak and the sides of lateral ridges branching from it; or else on somewhat detached peaks, some of them ten to twenty miles west of the Cascade divide. Of these outlying groups of glaciers, the most numerous are at the heads of high grade valleys in the granitic peaks about Monte Cristo, as has been observed by Bailey Willis, and on similar granitic peaks bordering the upper course of Skagit River. There is also an outlying group of glaciers on Mt. Baker and neighboring mountains.

The broadest névé fields and most numerous glaciers occur on Glacier Peak and the rugged mountains surrounding it. The snow fields in this region cover a rugged area some ten square miles in extent, and are confluent; from this gathering ground there flow several short ice streams, or rather ice tongues, as none of them have a characteristic stream-like form. The névé extends up the sides of the culminating cone of Glacier Peak and occupies the remnant of a crater still recognizable at its summit. From the top of Glacier Peak fully fifty glaciers are in view within a radius of about thirty miles. But little, if any, difference in the distribution of these glaciers can be recognized, on looking northward or southward, thus indicating that their existence depends rather on general climatic conditions, than the occurrence of previously formed cirques, or the shelter afforded by lofty peaks.

Lituya Bay, Alaska.—This bay was visited and mapped by La Pérouse, in 1786. It has the shape of the letter T. The cross arm of the bay was not surveyed but was drawn in from descriptions of the officers who visited it. La Pérouse speaks of five large glaciers coming down to the water, two at each end and one at the side of the cross arm. The maps of the Canadian Boundary Commission, made about 1894, show that the side glacier has diminished, but that the two glaciers at each end of

ay have coalesced and advanced nearly two miles (*O. K.*

. William H. Dall, who visited the bay for the United Coast Survey, in 1874, thinks that these glaciers were ly a mile or more shorter then than the Canadian map them to be now; so that the advance seems to be still ssing.

xico.—The glacier on Mount Iztaccihuatl is advancing *rdottes*).

HARRY FIELDING REID.

OLOGICAL LABORATORY,
NS HOPKINS UNIVERSITY,
March 27, 1899.

NANTUCKET, A MORAINAL ISLAND

A GEOLOGICAL MODEL OF NANTUCKET

THIS model (made at Harvard University), size 1
inches, scale 1:62500, or about an inch to the mile, is b
the United States Geological Survey topographic map
and on information from the latest geological survey
island. It was with the aim of producing an instructive

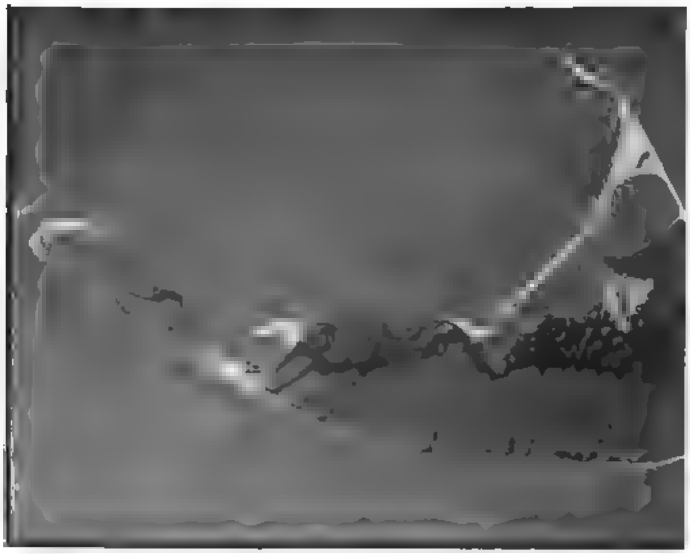
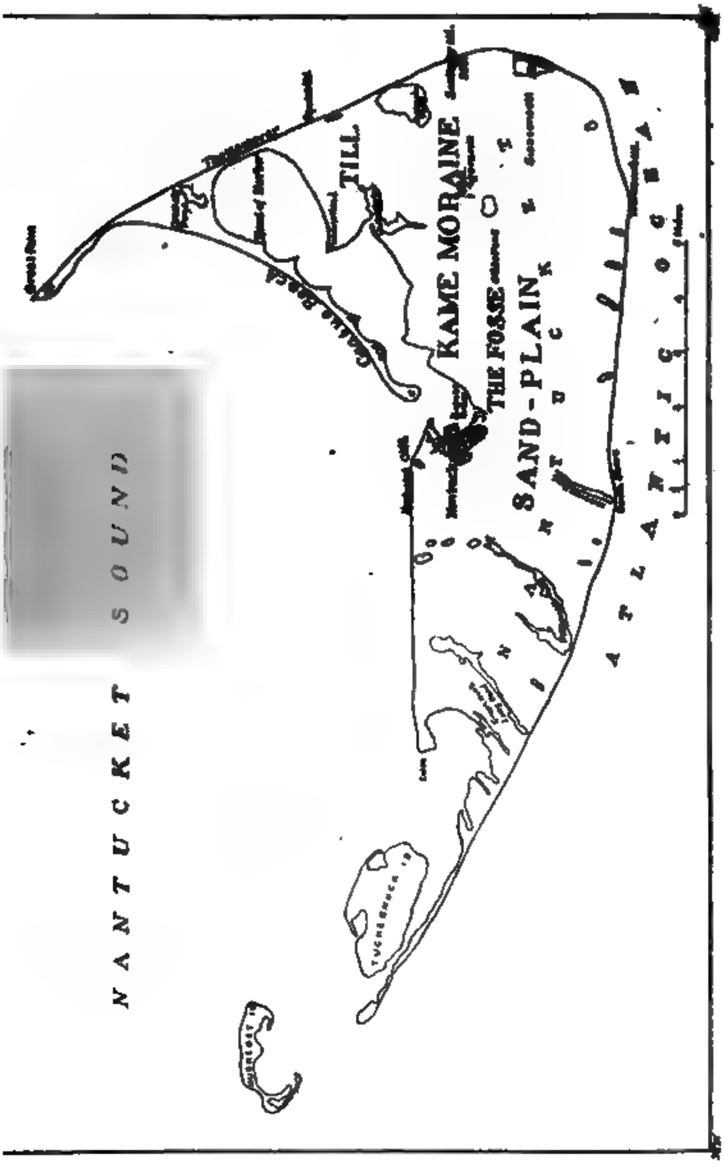


FIG. 1.—A Geological Model of Nantucket.

this portion of the deposits of the great continental
which here forms a type example of a morainal island,
model was undertaken.

The principal topographic features,[1] shown by a pr

[1] After report on "The Geology of Nantucket," by PROFESSOR SHALER
Surv., Bull. 53, 1889; surveys by J. B. WOODWORTH, U. S. Coast Survey,



OUTLINE MAP OF NANTUCKET.

the island (Fig. 2) may be briefly described under ıg divisions.

ground moraine: an area of irregularly distrib- us, the undifferentiated till which lies on the ›art of the island in the vicinity of Pocomo ee map, Plate I.)

kame moraine: a belt or ridge of kame-like ıd kettles from 20 to 100 feet in altitude, ıing through the middle of the island, seems s back bone. On its south side, the kame escending to the 40-foot level, grades sud- a smooth-bottomed trough, which reaches ı of over one half a mile in its widest part. ɛrn side of this depression ascends 40 feet by lope into the head of the sand plain. This :onformation lying between the kame moraine rth and the sand plain on the south, runs the extent of Nantucket, and Tuckernuck, en termed:

fosse.—It is supposed that this depression resting place of the ice, while the steep slope ıe head of the sand plain marks the position front during the building of the frontal plain,)ment at the head of the sand plain has been *:e-contact slope.*

glacial sand plain: which, falling gently from at its head to the sea on the south, represents ıd gravel deposited from the streams as they n the glacier front. The plain has a relatively face, sloping in its two miles of extent, from level to the cliff where the sea has cut the /el. At rather regular intervals of a quar- le, the plain is interrupted by shallow troughs. :e very gently into the head of the sand plain, ue southward until truncated in their deepest by the seashore. These creases are today

FIG. 2.—Profile Section across Nantucket Island.

practically dry, and represent the old drainage channels o glacial time. Some of them can be traced, not only toward th head of the sand plain, but extend quite through the kam moraine to the harbor on the north.

5. *Ponds or lakelets.*—There are several types of ponds o Nantucket. The most prominent lie in the lower ends of th long narrow drainage channels across which the along shoi action has built barrier beaches. Hummock Pond, Long Pon Micomet Pond, etc., are the largest of these basins. Sachacl and Gibbs Pond, by their circular forms alone would seem to be different origin. Gibbs Pond lies in a depression of the foss Sachacha in a depression in the kame moraine across which barrier beach has been thrown. Croskaty Pond is simply tl unfilled enclosure between the trailing spits of Coatue Beach ai Great Point. On the inner side of Coatue Beach, lagoon-li ponds have been formed behind the successive growths of sha cusps. "Three of the cusps on the inside of the Coatue Spit, ha no lagoons, but as the other two have, and since they are neai the end of the spit and hence probably later formed, it is qu likely that the earlier formed forelands also began with lagoons.

Professor Shaler has ascribed these Coatue cusps to tic whirlpools. He says: "From a superficial inspection it appe that the tidal waters are thrown into a series of whirlpools, whi excavate the shores between these salients and accumulate t sand on the spits."[2]

6. *Marshes and swamps* are plentiful and of origin similar the ponds, the swamps as a rule being but the more advanc stage of pond-filling.

7. *Shoreline topography* is well exemplified. Nantucke south side shows a coast well straightened by the dominati currents; the irregularities have been smoothed by beachi across the inlets and nipping the sand plain. A large part the eroded material has gone to build up both the long sj extending toward Tuckernuck, and the rounded cusp or "aproi

[1] F. P. GULLIVER: Proc. Am. Acad. Arts and Sci., Vol. XXXIV, 1899, p. 219.

[2] Bull. U. S. Geol. Surv., No. 53, 1889, p. 13.

which lies between Tom Never's and Sankaty Heads. Greta Point is made from the waste of the cliffs on the eastern side. Coatue Beach represents the tendency of the waves to straighten the north shore.

These shore forms are changing rapidly. The spit formerly lying in front of Tuckernuck, for example, has been driven back and the island cliffed, sending out two wing bars, the western reaching a little beyond Muskeget.[1] At "South Shore" the foreland has been aggrading, while the blunted cusp near Tom Never's Head has worn nearly away.

Ten years ago Professor Shaler wrote:[2] "About one third of the coast line of Nantucket appears now to be undergoing erosion. At the eastern extremity of the island the erosive action appears at present to be limited to the section from the southern end of the Sankaty bluffs to a point just beyond Haulover Beach at the head of Coatue Bay. In 1873 Professor Henry L. Whiting found by a resurvey of this portion of the shore that the eastern or sea side of the coast at the Haulover had receded by an average of about one hundred feet since 1846. Between Sachacha Pond and the Haulover, especially at Squam Head, the wasting is evidently at this day quite rapid, probably amounting to at least a foot a year. The southern coast westward from Tom Never's Head, especially the section west of Weedweeder Shoal, is also the seat of considerable, though apparently inconstant, wear. A remarkable but probably temporary change has recently taken place in the long spit which forms the western extremity of the island as it is delineated on the Coast Survey maps. Twenty years ago this spit at low tide constituted an almost complete bridge extending from Nantucket to Tuckernuck Island. Of recent years this point has in good part been washed away almost down to its base near Further Creek. It seems possible that the existing separation of Tuckernuck from Nantucket may have been brought about by the action of marine currents within a relatively short time."

[1] U. S. Coast and Geod. Surv. chart, No. 7, 1898.

[2] *Op. cit.*, p. 51.

The following table gives the geological horizons recognized at Nantucket and the corresponding topographic features which are represented in the legend of the model by separate colors.

POSTGLACIAL	RECENT	Swamps and Marshes	
		Ponds — four types	
		Shoreline; beaches, spits, bars, cusps, cliffs	
PLEISTOCENE	LAST GLACIAL EPOCH	Ground Moraine	
		Kame Moraine	Terminal Moraine
		Fosse	Terminal Moraine
		Frontal Sand Plain	Terminal Moraine
	OLDER PLEISTOCENE	Sankaty Beds, shell deposits	
CRETACEOUS		Clays — artificially exposed (not indicated)	

I am indebted to Professors Shaler and Davis, and Mr. M. S. Jefferson, for helpful criticism on this model, and especially to Mr. J. B. Woodworth, whose valuable aid has much increased its merits.

G. C. CURTIS.

A SKETCH OF THE GEOLOGY[1]

The island of Nantucket, which has been made the subject of a model by Mr. Curtis, is one of the most instructive portions of the terminal moraine of the last ice epoch in North America, because it is the most distinct and isolated of these glacial accumulations. Set in the waters of the ocean far to the south of the morainal belt of Cape Cod, and distant nearly its own length from the neighboring island of Martha's Vineyard, the peculiari-

[1] Written by J. B. WOODWORTH at the request of Mr. G. C. CURTIS.

of its glacial form, despite the low relief of the island, are
dily discerned.

This island, more than any other one of the New England
nds,[1] approaches closely the purely morainic type. On Mar-
's Vineyard, Block Island, and Long Island, the relief is so far
uenced by the topography of folded and eroded beds older
n the moraine, that the true morainic expression is not fairly
n. It is in the nature of glacial drift to mask to a large extent
older rocks on which it lies. The drift of Nantucket affords
exception to this statement. Beneath this mantle of till,
vel, and sand, whose relief is shown in the model, there is a
ement of pre-Pleistocene clays and older Pleistocene beds,
ch are exhibited in the sea cliffs on the east coast, and again
the north shore. These pre-morainal beds give rise to certain
uliarities in the topography, forms which even the morainal
osits do not entirely conceal. Remove both the moraine and
plain of gravel and sand on the south side of the island, and
e older deposits would still stand above the present sea level
number of small islands, one at Sankaty Head, one at Squam
d, and a larger islet about the size of Tuckernuck, extend-
westward from the site of the town of Nantucket. Other
ll islets might remain where the later drift now covers these
r rocks.

The oldest known formation on the island is a bluish clay,
ably of Cretaceous age. This clay makes up the ridge south
west of the town of Nantucket. The beds of this series are
ly folded, as are also the strata of the same, and even more
nt, date in the islands westward to Staten Island. Beneath
e beds at an unknown but probably not great depth we should
ct to find the extension of the granites and gneisses of
heastern Massachusetts.

Newer than this oldest clay formation is a series of sands and
y clays containing a Pleistocene marine fauna, that of the
known Sankaty Head beds. That these beds are older than

[1] name proposed for the islands from Nantucket westward off the southern coast
r England, having a common geologic and geographic development.

the moraine is shown by the tilting and dislocation of the strata under the Sankaty Head lighthouse, their truncation by erosion and the unconformable deposition on them of the moraine, a relation first described by Upham, who showed that the beds do not belong to the so-called Champlain epoch as Dana was first led to suppose. Northward, at Squam Head, similar beds occur at high angles with folded clays, indicating that a profound disturbance of the strata over the site of the island took place sometime after the deposition of the older Pleistocene. Opinion is not unanimous concerning the cause of this and the similar dislocations which affect the islands of this group. According to one view, the dislocations originated in movements taking place in the earth's crust beneath, being simply a more pronounced phase of the disturbance which marks the "fall line" from New York southward at the inner edge of the coastal plain. Another view supposes the strata to have been disturbed by the mechanical action of an ice sheet advancing upon the soft strata of the Atlantic coastal plain. Since the action took place long before the deposition of the moraine which constitutes the chief feature of the island, the question need not be debated in a paper dealing primarily with the interpretation of a model of these more recent features.

The superficial formations of glacial origin on Nantucket appear in three very distinct belts extending east and west across the island and appearing on the dependent island of Tuckernuck. The small, wave-washed isle of Muskeget is probably a modified remnant of one of these belts. These deposits reappear on the easternmost part of Chappaquiddick. These bands may be spoken of as the kame moraine, the fosse, and the frontal plain. North of the hummocky ground, known as the kame moraine, in the eastern part of the island, is a small area of till-covered land. It seems to be the unstratified débris left upon the surface when the ice-sheet melted away, and may be dismissed with this explanation. Everywhere bordering the island is a fringe of recent marine deposits, in the making of which the original outline of the island has been much altered.

The significant features in the glacial formations are assembled in the accompanying diagrammatic cross section.

It is most convenient to consider the frontal plain first in describing the above named features of the island. This plain begins rather abruptly on the north as a terrace overlooking a more or less depressed region. The height of the plain along

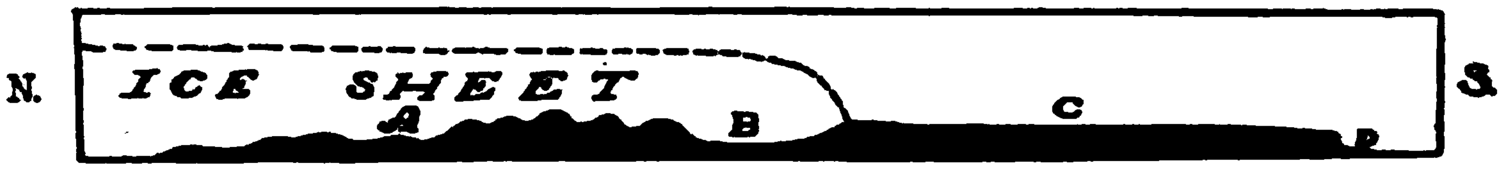


Fig. 4.—Cross section (diagrammatic) of the Island of Nantucket, showing the relation of the kame moraine (*A*), the fosse (*B*), and the frontal plain (*C*). *D* is the present beach. The dotted line represents the supposed profile of the ice sheet when the frontal plain was building.

this summit line is, where greatest, about 60 feet above the sea level. The slope of the terrace to the fosse on the north is well marked, but not so steep as that of the typical moraine terrace of Gilbert,[1] or so sharply cuspate as the ice-ward edges of the sand plains described by Davis[2]. Yet this slope taken in connection with the fact that the plain inclines southward with well defined drainage creases, and that the materials are coarse at the crest line and grade into finer gravels and sands southward, affords good evidence that the plain was built against the front of the ice-sheet by excurrent streams. Viewed in this light, the terraced head of the plain indicates the east and west line along which the ice front stood in its southernmost extension.

This ice-contact slope is most distinct in the eastern part of the island, where it turns to the southeastward, as if the ice sheet extended seaward in this direction, covering at least the area now forming the Nantucket shoals. In the vicinity of the town of Nantucket, the hillock of pre-Pleistocene clays already mentioned has given rise to the type of sand plain which is dominant on Martha's Vineyard, one in which for the greater part of that island, the top of the sand plain was not built up to the base of the ice front where that rested on elevated ground. On the

[1] Lake Bonneville Monograph I, U. S. Geol. Surv., 1890, pp. 81–83.

[2] Bull. Geol. Soc. Am. Vol. I, 1890, p. 195.

western part of the island and again on Tuckernuck, the ice-contact slope can be distinguished, affording a base line of reference from which to work out the relations of the glacial deposits to the ice sheet.

Accepting the slope at the head of the plain as denoting the position of the ice front, it follows that the fosse and the kame moraine are features originating in the area occupied by the ice. The fosse is simply the unfilled ground between the head of the plain and the belt of accumulations known as the kame moraine.

The kame moraine is supposed to be contemporaneous with the sand plain; one was building up by the action of excurrent streams outside of the ice while the other was accumulating inside the ice by the combined action of ice and water. This idea that the kame moraine is not frontal but submarginal in relation to the ice sheet by which it was built, first suggested, it is believed, by Salisbury for certain portions of the terminal moraine westward on the mainland, is consistent with the interpretation which has been placed on the origin of the kames near the heads of sand plains. Both ice-laid and water-laid drift tend to accumulate in the form of knobs and basins in this situ ation. At present, the explanation of the phenomenon can hardly be said to rank as an hypothesis, much less as "demonstrable theory."

One supposition is that the kame moraine marks the site of an earlier frontal deposit, *e. g.*, a sand plain, subsequently overridden by the ice sheet in its advance to the line marked by the head of the frontal plain. Stratified beds of sand and gravel seen under a coating of till in patches of kame moraine, as at Bridgewater, Mass., and the sandy clays under the till of the Nantucket kame moraine, show the possibility of the extra-glacial origin of the original deposit. But this explanation does not account for the seeming regularity in the occurrence of the belt of kame moraine at a distance of from half a mile to a mile back of the head of the outwash plain.

A second supposition makes the kame moraine built up under the lip of the ice sheet in the manner in which débris was seen

accumulating in that situation by Chamberlin in the Greenland glaciers. Applying the observations made by Chamberlin upon the shearing of the upper ice over the lower and the involution of drift which thus comes about, to the case of the Nantucket type of terminal moraine, we may fairly suppose that when the moving ice sheet became blocked against the head of its growing sand plain, the upper ice began to shear over the lower, blocked prism of ice lying behind the sand plain. This shearing movement affected the lower part of the ice sheet for a long distance back from the actual front. At a distance of from one

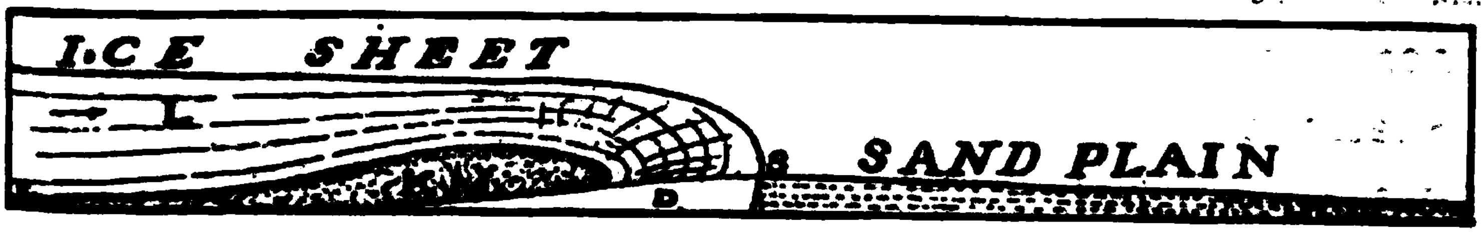


FIG. 5.—Diagram showing supposed mode of accumulation of Kame moraine. *D*, Prism of dead ice blocked by sand plain barrier. *L*, Live ice dragging up drift into K M, the position of the Kame moraine. *S S*, Principal plain of shearing.

to two miles back from the front the bottom ice began to glide over the prism of dead ice lying back of the sand plain. (See Fig. 5.) As a result of this action the subglacial till dragged along on the bottom northward of this belt was gathered in the shear zone with moving ice above and dead ice below. Most of the till accumulated within a belt about a mile wide, leaving a strip in the case of Nantucket from a mile to half a mile wide between this accumulation and the head of the sand plain in which the débris was small in amount as compared with that deposited in the sand plain on one side and in the moraine on the other. On the melting out of the ice sheet, this outer part of the stagnant prism of ice, which was relatively free from drift, would give rise to the depression which separates the sand plain from the moraine. The melting out of the inner thin portion of the wedge of dead ice with its charge of till would result in the hummocky topography which gives the moraine the striking resemblance to a belt of kames. In the case of the water-worn gravels and sands which accumulate in this belt, it is to be supposed that in the shearing movement of the upper ice over the

lower stagnant prism of ice, the subglacial drainage is interrupted and the detritus is involved in the movements of the ice as in the case of the till. It is favorable to this view that, in cases where such action may be invoked, eskers are absent, and the sand plain appears to have been fed by streams flowing off the ice sheet.

Certain ponds and furrows which lie in the kame moraine belt show that the drainage of the ice sheet, perhaps a late phase of the system, coursed through the field quite independently of the motion of the ice, which may well have been stagnant at the time. On the east, the furrow connecting Polpis harbor with the drainage crease in the sand plain has been noted by Shaler, as an indication of the movement of subglacial water as in a pipe to the front. On the other hand, creases west of the town connecting with deep, pothole-like ponds in the moraine belt suggest the holes at the bottom of falls of water off the edge of the ice sheet rather than depressions due to the melting out of blocks of ice.

The question of sea level in relation to the sand plain at the time it was building is a debatable one. The absence of anything like wave action on the island above the present sea level is presumptive evidence that the sea has not stood higher than it now does upon this coast since the glacial formations were deposited. A comparison of the Nantucket plains with the deltas of glacial rivers such as those of the Malaspina district in Alaska and of Heard Island in the Indian ocean would lead us to regard the sand plain as made in the open air.

The student who is desirous of studying many interesting details concerning the geology and physical geography of this island should supplement this brief account of some of its features and the questions which they raise, by reading Professor Shaler's report on its geology.[1]

J. B. WOODWORTH.

[1] The Geology of Nantucket. Bulletin No. 53, 1889, U. S. Geol. Surv., pp. 55. 10 plates. By N. S. SHALER. This work gives references to numerous other papers concerning the paleontology and moraines of the island.

BEACH CUSPS

A FREQUENT feature of our New England beaches is a succession of stony or gravelly cusps with sharp points toward the water, situated on the upper part of the beach where the waves play only at high stages of the tide. My attention was first called to these cusps by Mr. J. B. Woodworth, of Harvard University, under whose direction the general view, Fig. 1, was taken for the U. S. Geological Survey. Subsequent study on Lynn Beach, Mass., where I obtained twenty instantaneous wave photographs, has satisfied me that on that particular shore the cusps must be ascribed to the agency of the seaweed piled up on the beach, modifying the action of the greater waves. The successive stages of construction shed so clear a light on the local

FIG. 1.—Westquage Beach, R. I.

forms, and the weed control has seemed so clear through a great variety of details observed on this beach during more than two years, that it seems time to call the attention of other observers to the point involved. Any beach photograph may have a record on it of some stage of these beach cusps.

The portion of Lynn Beach where these studies were made

is at the junction of the Nahant barrier beach with the mainland about one hundred yards north of Hotel Nahant. It opens to the Atlantic a little south of east and is on the Boston Bay sheet of the topographic map, in latitude 42° 27' 30", longitude west 70° 57' [illegible]. A masonry wall with a concrete walk above here caps the beach. Just below this is a mass of rounded stones from two to six inches in diameter, which have been flung up in storms. These are attached to seaweed, having been derived from the bottom off shore.[1] This belt of cobblestones passes into the sand of the beach proper by the series of cusps above mentioned. The seaward side of the heap of cobbles is, as it were, eaten out in bays, twenty to thirty feet wide with residual points or cusps between. In the bays, the slope descends one foot in four to the almost level beach of fine sea sand. Along a line roughly tangent to the bay heads, and thus cutting across the stony promontories between, there is found an almost continuous wall of seaweed. The bays in the cobble line are floored with a gravel of texture intermediate between the stones above and the sands below. The stony points terminate in slopes much steeper than the bay floors. The gravel of the bay floors itself advances upon the beach in a series of cusps, well outside the stony points and alternating with them.

The outer undulating margin of the gravel points on the sand is usually thinly strewn with cobbles from the belt above. These details may be made out more clearly with the help of the accompanying diagram, Fig. 2. The constant *recurrence* of bay and point as one walks along the beach suggests that there is a regularity in width of intervals. This is not so, however, on Lynn Beach, as appears from the diagram, measures from point to point along the beach being 21, 20, 18, 16, 22, 17, 6, 7, and 22 paces. Further cusps farther south toward Nahant show similar irregularity. It might be said, however, that on Lynn Beach they are commonly about twenty paces wide.

The work of the waves on the beach depends on their magnitude and direction, and on the stage of the tide. The magnitude

[1] SHALER: National Geographic Monographs, Beaches and Marshes, p. 144.

of the waves varies primarily with the wind. The great rollers that tumble up a beach some days of calm are due simply to a distant wind whose effect is transmitted faster through the water than through the air. For beach work, however, we must distinguish two orders in the magnitude of waves that follow each other even in a brief period. Anyone who visits a beach may satisfy himself that at fairly regular intervals there occurs a great wave, far overtopping the average in height and extent of

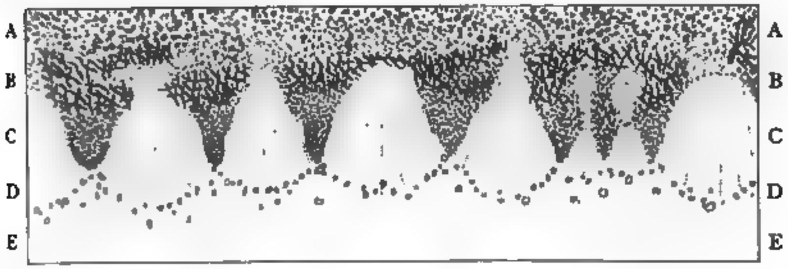


FIG. 2.—Diagram of Beach Cusps.

AA Zone of Cobbles. CC Stony Cusps.
BB Zone of Seaweed. DD Gravel Cusps.
EE Flat Beach of Sand.

advance up the beach. Now this great wave is as much more efficient than its fellows for beach work in ordinary weather, as the work of a single storm outweighs months of normal tides in building and modifying features of shore topography. As regards the stage of the tide, in a similar way, spring tides are the occasions of maximum beach work in average weather. This is especially true in all that concerns the upper beach line, where our gravel cusps are situated. All the waves, great and ordinary, have an excess of shoreward over off-shore movement during rising tide. Generally speaking it is thus during the rising of the tide that objects are driven up the beach, and during the fall that they are drawn out seaward, unless left stranded, as must happen in most cases, since both forces, though opposite in direction, have least intensity at the shoreward margin of the beach.

It results from these considerations that the greatest amount of stones and seaweed will be flung up on the upper beach on the rise of a spring tide when a strong gale is blowing from the east. The beach is not, however, a convenient place for observation at such a time, nor can it be visited save by observers resident in the neighborhood on account of floods and washouts that result and interrupt railroad and other travel. For this reason it is more practicable to study what occurs during spring tides with only moderate winds.

Such an occasion was November 7, 1896 when I was fortunate enough to reach the beach shortly before high tide. The ordinary waves were playing up and down the bays as far as the belt of seaweed, SS, Fig. 2. These waves advanced with a front indented by the stony points at their maximum advance. But at intervals of about ten minutes a great wave broke evenly upon the line of seaweed, sending tons of water over the cobblestones above. The zone of seaweed in the diagram should be understood to have a depth of 12 to 18 inches. Shoreward from the crest the weed slopes and thins. It is more or less present even on the cobble belt [illegible]. But the zone represented on the diagram marks the crest. Immediately after breaking, the wave [illegible] the zone SS [illegible] leaving considerable masses of water [illegible] behind the weed. This can only escape through [illegible] breaks in the line of seaweed and at these points [illegible] straight out seaward. This moment is [illegible] Fig. 3. The wave has just broken evenly along the [illegible] represented by Fig. 3 the water may [illegible] from right and left behind [illegible] through the break in the weed where [illegible] direction. A similar [illegible] the opening of another [illegible] water flung behind the [illegible] sufficient to [illegible] during the rise and fall [illegible] up and down the bays [illegible] the stony promontories

which are completely buried in Fig. 3, and the bays between. We also note that each break in the seaweed exactly marks a bayhead. The gravel cusps below are still beneath the water. On one occasion I saw a continuous wall of seaweed flung upon the beach, saw the water ponded behind it until finally weaker points in the wall yielded to the pressure and broke, and openings were established that guided the outflow of all subsequent great waves. It seems to be clear that the bays between

Fig. 3.—Moment of wave retreat.

the stony promontories are scoured out by water escaping from behind the barrier above. That weak points should occur is inevitable. It is not conceivable that the waves could cast up a line of weed so perfectly homogeneous as to present the same resistance to outflowing water all along the line. Once a current is established across the crest, its lightness causes the weed to float away in the stream until the pebbles below are bared, and then washed down the beach in the narrow rushing stream. The weed where unbroken protects the stony ridge as the paper pattern protects glass from the sand-blast. Furthermore it concentrates the water on the unprotected spots. It may be thought

that a stony barrier might play a similar part on a beach where seaweed was absent. Great waves would surmount the crest and the water caught behind escape as best it might to the sea. Low places would doubtless occur in the crest of the line and some water flow over them. But it is to be expected that the water would filter through the mass rather than wear channels, owing to the greater specific gravity of the barrier. It is unlikely that bays could be cut out in the stones under such circumstances. It would seem to follow that such stony cusps are to be looked for only on coasts where seaweed or some similar material is abundantly thrown up.

As the tide falls, presently the waves cease to surmount the crest of the weed and each wave in receding discloses more and more of the lower beach. It now becomes evident that the scouring waters that have been rushing down the bays have spread the gravel with which they are visibly loaded in a great fan at the mouth of the bay, fairly underlying the wave-fan seen in Fig. 3, outside the seaweed. It is a true fan delta built by the stream where its waters are checked by the relatively stagnant waters outside. As these deltas are built out in front of the bays it results that in this outer line of points bays occur opposite the points of the inner stony promontories. This is at once clear on the diagram (Fig. 2). Walking along the beach at low tide the delta fans are seen nearest and are more in evidence than the stony or original cusps above. These upper cusps may well be called *residual*, as they are remnants of a continuous line in which the bays have been scoured out here and there. At Lynn the residual cusps are stony but that is not essential. In Fig. 1, the whole material is apparently fine beach sand. The seaweed that originated the form is here hardly visible but enough is on hand to show that it occurs on the beach. Attention should be called here to the fact that seaweed shrinks enormously on drying. I have made no measurements and have no data at hand, but sugar-cane, with which I am familiar, contains nearly three times as much juice as wood, and cane has certainly more woody fiber than most seaweed. For this reason

a heap of weed that may while fresh considerably modify the waves, may become quite inconspicuous when dry. Considerable quantities of weed are also carted from the beaches for manure. The only sure way to determine the presence or absence of seaweeds on a beach is to visit it immediately after on-shore storms have torn up the bottom just beyond the low tide mark. The residual cusps in Fig. 1 are rendered unusually

FIG. 4.—Residual and Delta Cusps.

visible by the wetting of a portion of their line in what seems to be an ordinary wave of a rising tide. The original photograph shows the delta cusps distinctly alternating with the residual cusps above. At Gay Head I have seen only the residual cusps, which are there constructed of pebbles an inch or two in diameter and derived from the till topping the cliff above. At that time the form was unintelligible to me, but now I am sure that at lower water the delta cusps will be seen at Gay Head too.

In Fig. 4 both series are well shown on Lynn Beach. The water stands in the hollows between the delta cusps, which show only their points on the left. The view was taken about two hours after high water. Half an hour later the waves break far

out on the beach, and only a steady trickle of water draining out of the ridge of stones and seaweed remains, in place of the violent rushing at high water. The contact of the delta cusps with the flat beach is now disclosed, and we see the cobbles already referred to strewn along the margin of the cusps (Fig. 5). The view is taken from a point on the edge of the flat beach itself and shows only the delta cusps, the residual cusps lying off farther to the left. The cobbles have probably come down the bays in the rushing streams that build the deltas. They are scattered quite at random at the foot of the delta slopes, as indicated in Fig. 2. The advancing waves of the next tide will doubtless drive some of them up the promontories on which the earlier waves are concentrated by the delta cusps.

But if the establishment of bays in the ridge of cobbles is to be ascribed to the great waves, the part of the ordinary wave is not therefore to be neglected, nor the waves of lesser tides sc long as they send the water at all into the region affected. Th ordinary waves intensify the form given by the gaps in the sea weed. Across the beach below all waves advance in long, eve lines. As these come to the delta cusps their front is broke into tongues which are concentrated into the outer bays an made to impinge on the residual cusps in advance of the wate which comes to the inner line of bays. Of all the details of th wave-work, this is one of the best established. As the wav thus concentrated on the stony promontories tries to surmoun them, it is more and more deflected to right and left by the steep ness of the cusps. Thus, when the wave recedes, almost all th water runs down the inner bays. This was first seen at Ga Head, where I have a record in photographs. The bays thu have a preponderance of seaward scour. On Lynn Beach thi point was studied by gathering bricks along the shore and throw ing them in front of the points of the stony promontories. C twenty bricks cast into the sea where the two fans meet in Fig 3, corresponding to the second stony point from the left in Fig. one went across into the bay alongside with the next incomin wave; then a great wave brought all over the ridge of seawee

Some at once went on down into the bay alongside, whence they were finally removed seaward by the play of ordinary waves. Of a hundred stones flung into one of the bays, more than half were carried seaward in twenty minutes, and the others were half buried in the gravel by the scouring water digging pits in front of them. On another occasion my hat blew into the water in one of the bays, and in spite of some wind off-shore, was soon cast up on one of the promontories. There is some travel of

FIG. 5.—Delta Cusps and pebble fringe.

material shoreward up the promontories and much travel down the bays toward the sea. The great wave drives a good deal of material on shore.

The cobbles that descend over the fan deltas to the beach margin, and again ascend the promontories at the next high water, do not necessarily return to the point in the stony belt above from which they descended. It is probable that with winds setting more or less obliquely along a beach the descents will be made constantly to the right or left of the descents. I think I have seen something of the sort on Lynn Beach, but the observations were not sufficiently continuous to make this certain. In this case each cobble is liable to travel *epicycling* along

the beach, now up, now down, but always along in some lateral direction. In this form a short journey along the beach means a much longer journey along the actual path of travel, and longer opportunity for the attrition that comminutes all beach material.

On any beach where cusps occur the waves may be seen scouring out the bays and building fan cusps below. If it be asked how this begins, the answer must be that the beginning is as old as the beach. When first a ridge of cobbles was flung up by the waves and seaweed driven upon it with the rising tide, there came a moment when a great wave broke on the ridge crest to send a rush of water further shoreward. This water escaping guided the scouring of the first bays in the stony ridge. In these the waves will continue to play, deepening the scour ways, lengthening the delta cusps, and working over and modifying the mass till another spring tide or another on-shore gale builds a new barrier with stones and seaweed newly torn from the bottom. Each set of cusps may modify its successors. A new crest of seaweed flung up today is likely to have its weak points in some measure determined by the previous channels. In violent storms it is doubtful if this control is significant. Each storm probably sets the shape in which the waves must play for a long time.

As these studies have been made at a single beach, though confirmed by some observations from Gay Head and Narragansett Bay, corroboration or modification of the interpretation by others would be welcome.

MARK S. W. JEFFERSON.

A CERTAIN TYPE OF LAKE FORMATION IN THE CANADIAN ROCKY MOUNTAINS

In the Rocky Mountains of Canada there are abundant evidences of the great Pleistocene ice invasion. During considerable travel with pack horses through the valleys of the most easterly or summit range the writer had occasion to cross the continental divide by five different passes, from the Simpson Pass on the south to the Athabasca Pass on the north. This gave a familiarity with the range through a degree and one-half of latitude, or from 51° to 52° 30′ N. The evidence was everywhere so constant that a more extended region would undoubtedly reveal the same indications of a former ice sheet.

The general topography of the Rockies in this region is exceedingly rough, the mountains being disposed in long ridges, with peaks from 8000 to over 13,000 feet high, with deep, narrow valleys between.

In order to understand the special type of lake formation to be discussed, it is necessary first to review briefly the general results of former glacial action in the region. These results are evident in the drift, striations and grooves, the transportation of erratics, and in glacial contours.

Drift, consisting of unstratified clay deposits containing angular and glacially striated stones, covers the valleys and passes throughout the region examined. It varies in thickness from a thin layer up to observed sections of more than 300 feet. It is generally thickest in the valley bottoms and on the lower slopes of the mountains up to an altitude of about 500 feet above the stream beds. Above this level it gradually thins out, leaving the mountains bare at from 1000 to 2500 feet above the valleys.

Drumlins occur in many valleys, especially in those now occupied by large streams, and in some regions are so abundant as to become the most prominent feature of the landscape.

he phenomena of crag and tail, like the drumlins, are ve ant and no less important in determining the direction :e movement. Crag and tail assumes all gradations betw s several miles in length to those that are merely shal nulations of drift in the lee of slight elevations of the r :e.

FIG. 1.—Section near Banff showing two tills.

:rminal moraines, except near existing glaciers, are far :nt than the subglacial drift formations. Modified drift terraces are well marked on all the rivers as soon as t the plains; also in the mountain valleys of the Athaba tchewan, and Columbia; but the smaller rivers and stre show well defined terraces in the mountains themselve

Several exposures of the drift showed evidence of two ice invasions. One of the clearest of these was discovered on the banks of the Bow River, two and one half miles east of Banff Station, on the Canadian Pacific road. Here the river sweeps against its north bank, and has laid open a section of drift more than 300 feet thick. About half way up the bluff the line between two different kinds of till is clearly marked.

The lower till is of unstratified drift, consisting almost wholly of pebbles and gravel, with but very little clay and rock dust. Quartzite, limestone, and argillite pebbles, many of which are markedly striated, make up the principal mass.

The overlying till consists almost wholly of clay, so hard as to resemble sun-dried brick, which, when struck by a stone resounds like solid rock. Interspersed at considerable intervals are pebbles not differing much from those of the lower till. Like them they are angular and striated. The bottom of these formations is not exposed, as the river rests on drift. However, two formations were later observed on the Cascade River two miles distant, which were identified as the same, and these rested directly on the Cretaceous sandstones of the vicinity. Thus only two tills are represented in this region.

The sides and summits of mountains must be examined for evidence of greater depth in the ice currents than those given by the drift formations. Near the station of Banff, which is in the Bow or South Saskatchewan Valley, about twenty-five miles from the point where the river leaves the mountains, there is a low mountain whose summit is exactly one thousand feet above the river. This mountain is of Devonian limestone throughout, and in form is a blunt ridge running transversely across the valley and partially blocking it. On the top of this mountain there are many Cambrian quartzite bowlders and other erratics which have been transported thither. The nearest point at which these quartzite bowlders are found in place is at Castle Mountain, seventeen miles up the Bow Valley. The limestone ledges are channeled, grooved and striated, in a direction exactly across this mountain, but parallel with the valley.

This mountain, therefore, must have been so deeply cov by a glacial stream that a barrier one thousand feet high ca no deflection of the current.

Proof of higher points being overrun by the ice was obse on Stony Squaw Mountain, which rises to a height of (feet, or 1620 feet above the Bow Valley, and is a little to northwest of the point just referred to. The mountain contours rounded by ice action and the higher parts are from débris or soil except for a few quartzite erratics, of which more than two feet in diameter, was found on the very sum This mountain also is of Devonian limestone formation and sequently the bowlders have been transported hither by gl action.

The mountains in the neighborhood of Banff show glac rounded contours much higher than the summits of the l points just referred to. Grooves running parallel to the va direction may be observed on the limestone cliffs of the m tains, from the valley bottom itself, especially in certain cc tions of the light. Some of them are between 7000 and ; feet above sea level, and indicate that the ice was bet 2500 and 3000 feet thick in this region. Up to 7500 feet al the Bow Valley at Banff, the evidence of general ice actic quite certain, but higher than this all is more or less obs A distinction must be made between the work done by l glaciers of the mountains and the general currents filling valleys, but this is not usually difficult as local glaciers, unlik general currents, were affected directly by the mountain slc

Evidence from other parts of the mountains is in accord with these conclusions. Thus near Lake Louise, forty n northwest of Banff, in the Bow Valley, striations of a ge ice current were found on the summit of a mountain 7350 above sea level. Glacial contours are evident about 350 higher, or 7700 feet above sea level.

Continuing up the Bow Valley about ten miles, glaci contours reach an altitude of about 8000 feet. Fifteen r further up, where the river takes its source, near the Little

'ass, the altitude is still higher, and reaches 8500 feet above sea :vel. On the other side of the pass in the valley of the Little 'ork of the North Saskatchewan, the evidence is almost identi-al, but with a downward slope of the ice line as the valley escends to the northwest.

The highest erratic was found on a point near Mt. Assini-oine, about twenty-five miles south of Banff, on the summit f a mountain of limestone formation 8650 feet above sea level. n the course of very many mountain ascents no transported owlders were ever observed at a greater height than this, nor n isolated summits over 9000 feet above sea level were there ny evidences of general glacial action.

The indications of former large ice streams which occupied ll these mountain valleys are found not only in the Bow Valley ut in the tributary valleys of the Saskatchewan and Athabasca n the eastern side of the summit range, and of the Columbia n the western side. In fact no mountain valley was observed ı which the same evidence was not more or less apparent, and ıe line between glaciated and unglaciated surfaces rarely or ever appeared at an altitude lower than 7000 feet nor higher ıan 9000 feet. This ice line is invariably higher in regions of reat elevation, near high mountain masses, in elevated valleys nd on mountain passes. It is evident then, from the arrange-ıent of drumlins, crag and tail formations, glacial grooves and :riations, and the transportation of erratics, that the present rainage system was that of the ice currents, even at the time f their maximum development.

To this there are some interesting exceptions, as for instance, ı the Columbia Valley, where it appears that the ice formerly ıoved southwards and the river now flows northwards. To find satisfactory explanation is not difficult. This valley is excep-onal among the mountain rivers in having very little gradient ı that the river is sluggish and the valley is more or less vampy. In other words, it would require only a slight eleva-ın of the region to the north or a depression to the south to verse the direction of this stream. It is not necessary, how-

ever, to assume such a change in elevation, as a slightly greater precipitation in the north would have made this valley discharge its glacier to the south.

We have then, the following, as a summary of the indications of the nature of former glacial activity in this part of the Canadian Rockies:

1. Evidence in the drift formations that glaciers formerly occupied all the mountain valleys.

2. Evidence in certain till exposures that there were at least two distinct ice invasions.

3. Evidence from glacial contours, striations, grooves, and erratics no less than from the absence of them on isolated peaks over 9000 feet high that the former glaciers were between 1500 and 3000 feet in thickness, that their maximum height in the valleys was between 7000 and 9000 feet above sea level, and that the maximum glaciation of this region was always confined to the valleys, above which the very elevated regions and mountains, which were centers of dispersion, rose like islands.

4. Evidence, from the above, that the present drainage system represents approximately the direction of the former ice currents.

Having thus very briefly reviewed the extent of the ice invasion in the Canadian Rockies within the latitude specified, it is now possible to get a clearer idea of the special type of lake basin which is the subject of this article.

Lakes, though very numerous, are limited in size as would naturally be expected in a region of narrow valleys and steep gradients. The two Bow lakes at the sources of the river of that name, are each about four miles long by one mile wide. Outside of these lakes the great majority are smaller and are of all dimensions down to mere pools two or three hundred yards across. About one hundred of these lakes were more or less thoroughly examined and, in regard to their formation, may be divided into four classes.

1. Lakes formed in kettle holes of the valley drift, often in chains of three or four together. In this class should be included

; where water has collected in irregularities of the drift. ıre especially numerous near the summits of passes he nearly level surface has not permitted the streams to n and drain the basins. This class of lakes shows no

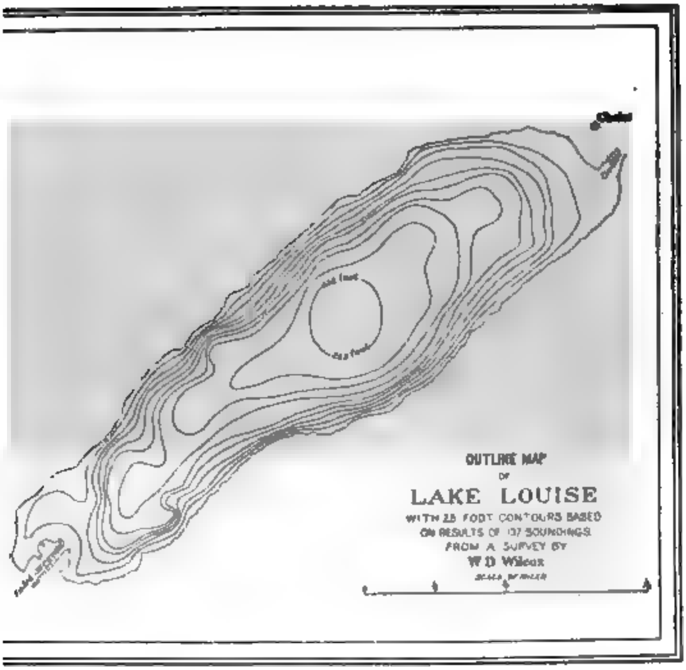


FIG. 2.

:y of form or location. Their basins are usually shallow, / frequently have neither inlet nor outlet.

akes dammed by terminal moraines. Only two of these ınd distant from existing glaciers. Each was about a g and the dam of one was two miles from the end of ;lacier and that of the other about four miles.

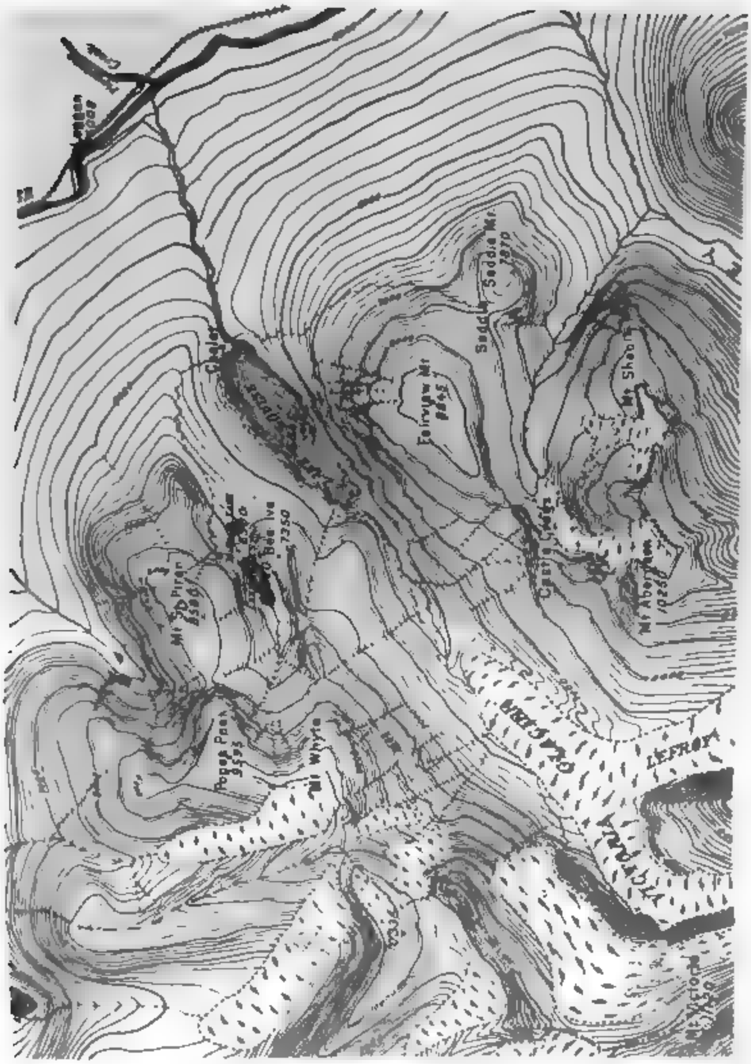
ock basin lakes. Only two of these were observed, one h was a typical cirque lake. Many rock basin lakes, , in this region are partially dammed by drift desposits, therwise of complex origin.

4. Lakes found just within the mouths of tributary valleys. These lakes are the most constant of all in their outline and position. They are invariably found where a lesser valley joins a larger one and occupy the mouth of the lesser valley. They are usually leaf-shaped and from three to ten times longer than wide.

Of this type Lake Louise is a good example and was made the subject of special study. Lake Louise is in one of the tributary valleys of the Bow River about twenty-five miles below its source, in latitude 51° 30′ N. and longitude 116° 15′ W. The shore line was carefully surveyed and mapped, after which the basin was studied by means of soundings. The accompanying map of this lake on which the contours represent the depression of the bottom below the surface, shows that the basin is very deep in proportion to its size. The basin is U-shaped with a nearly flat bottom, and with exceedingly steep sides approaching in many places a slope of forty-five degrees.

The lake occupies the end of a valley just above its junction with the much wider valley of the Bow. The catchment basin draining into this lake is an exceedingly rough part of the Rockies, with peaks over 11,000 feet high, forming part of the continental water-shed, at the valley end. The surrounding mountains are covered with considerable fields of ice, which unite to form a glacier about three miles long, measured up either one of its two branches.

A stream from the glacier has carried in clay and gravel so that a delta has formed, and filled in the upper part of the lake basin to the extent of one third of a mile or more. The fine mud carried by the glacial stream which is not heavy enough to sink at once upon reaching the quiet waters of the lake, remains suspended in the lake throughout the summer, and turns its blue-green water to a milky color by the end of August. In November the lake freezes, the inlet stream is much reduced in volume, and becomes clear, and the exceedingly fine mud settles to the bottom. This settling process continues under a thick protection of ice and snow for six months, and with few or no


LEFROY
GLACIER
VICTORIA

vection currents to disturb the quiet of the waters, the lake omes perfectly clear by spring.

An attempt was made to get a section of these clay deposits he lake bottom and so determine the age of the lake. It ned probable that by knowing the thickness of the annual osit, and by getting an entire section, the number of years e the formation of the lake could be estimated. For this pose a piece of iron pipe about one inch inside diameter was vily weighted and fastened to a stout rope. This was lowered ibout two hundred feet of water and allowed to fall the last r feet so as to carry the pipe far into the bottom. Upon ng the pipe out, and this was accomplished with great diffi- y, a core ten inches long was removed from the pipe by dry- Unfortunately this core did not represent the entire section he lacustrine deposits so that it would have been useless to ce estimates on this basis. As had been hoped, however, e were clear evidences of lamination in the slightly different ored bands of clay, though the structure was distorted by ig forced into the iron pipe. As nearly as could be counted e were about one hundred bands to an inch, and on the basis 10,000 years since the last retreat of the ice, these clay osits would have to be between eight and nine feet thick. h a more perfect apparatus and an entire section, the age of lake, and consequently the time since the glacial period, ht be quite accurately estimated.

The Lake Louise Valley has a trend to the east as it ers the Bow Valley, as though the former ice streams had ied down stream and swept over the flanks of the mountain he east side of the valley, while the other side shows a sharp e of drift descending from the base of a rock buttress 800 above the lake. This ridge carries a dam across the valley ith and slightly deflects the outlet stream to the right. The et stream has cut down through this dam and exposed a sec- of drift from 75 to 100 feet deep. It is typical till of hard, clay, with angular or striated limestones, shales and quartz- distributed through it.

The two valleys to the east which are similar to the Lake Louise Valley in size, direction and general features, have no lakes similarly located, but there is a more or less pronounced drift ridge on the upstream side of each. A swampy meadow in each valley corresponds in position to Lake Louise, and these meadows may represent filled-in lake basins.

Of the very many lakes of the Lake Louise type to be found in these mountains we shall only discuss one that was seen near

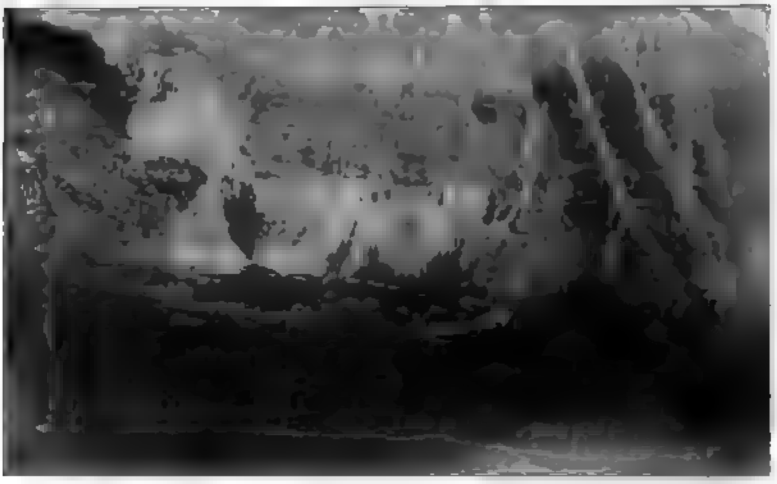


FIG. 4.—Lake near Mt. Assiniboine showing the dam.

the continental watershed in about latitude 51° N. at the base of Mt. Assiniboine, a mountain about 12,000 feet in altitude. The lake was small (Fig. 4), probably one third of a mile long and occupied the opening of a tributary valley to a stream of moderate size. Owing to distance from the base of supplies in this wild region, there was no time to make an examination of the ridge damming this lake, but it was undoubtedly of drift as was indicated by an abundant forest growth upon it. The shape of this lake, the position of the outlet, and the course of the stream deflected by the drift ridge, are clearly shown in the photograph. This lake is typical of this mode of formation.

A study of many cases showed that a certain ratio between the confluent valleys is necessary to the existence of this kind of lake basin. If the confluent valleys are nearly equal in size, thus showing that the glaciers formerly occupying them were probably of the same dimensions, the drift ridge projects as a long tongue between the two valleys and no basin is formed. If the ratio between the confluent valleys is about three to one or more, the drift ridge is thrown across the mouth of the lesser

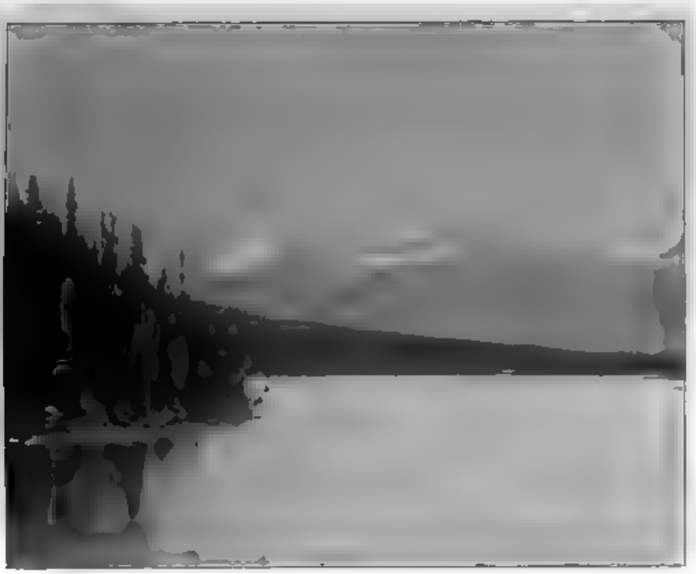


FIG. 5.—Lake Louise from the upper end showing the dam.

valley and a lake basin is formed. If, however, the ratio is exceedingly great, the lake basin will either be small, or totally lacking, and will be farther within the lesser valley, as though the lesser glacier had been set back by the great volume of the main ice current.

Many lake basins of this type have been entirely filled in by deposits of glacial streams and the growth of sphagnum mosses or forests which have made peat swamps or flat meadows where a lake basin formerly was.

So constant is this type of formation, that, upon seeing the ratio between certain mountain valleys, the existence and location of such lakes may be predicted with almost invariable success before the lake has been actually seen. The valley of the Little Fork of the Saskatchewan, which is about thirty miles long, has five streams from the west tributary to the main stream, and every valley has a long drift ridge on the upstream side thrown across the openings of the lesser valleys, resulting in the formation of three lakes and two swamps.

The outline of these drift ridges when looked at from a distance and at right angles to them is quite constant in character. Starting with the rock buttress where the formation commences, the drift is at first very steep and clings to the slopes of the rock. As it continues downward, the slope rapidly decreases in a graceful curve till it approaches an angle of about ten degrees. This slope continues through a great part of its length, only to increase again just before the ridge vanishes as a topographic feature. This curve is represented in almost every one of the many examples observed, and, like the outline of drumlins, may be a mathematical curve depending on the physical nature of ice. In general the outlines of these ridges are smooth like a drumlin or tail formation, and not like a terminal or lateral moraine.

A number of sections were found where streams have cut down through the drift and exposed sections from a few feet up to two or even three hundred feet. In all such cases the formation of the ridges was found to be a regular till without internal arrangement.

The horizontal projection of these ridges is slightly curved, and remarkably similar to what would be the lines of medial moraines on confluent glaciers from such valleys. Moreover these curves are assumed regardless of the lesser topographic forms and thus give another proof that they are not moraines.

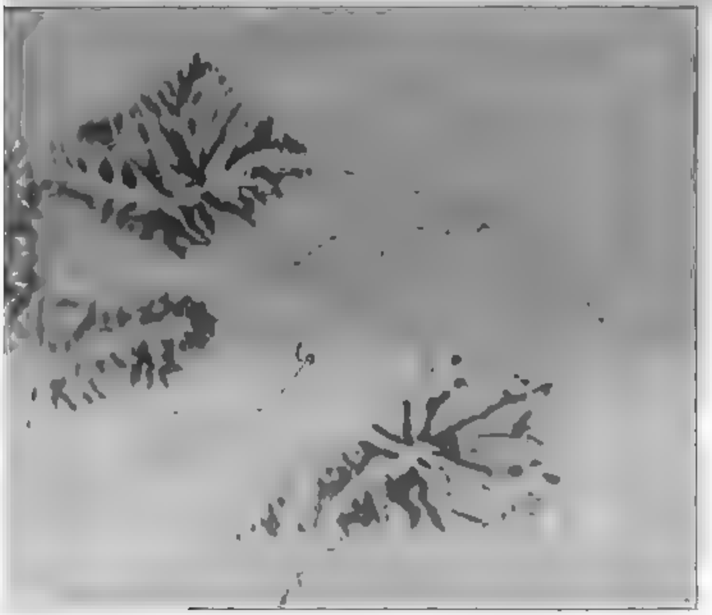
To summarize the characteristics of these drift ridges, we have the following:

1. Throughout the valleys of the region under discussion,

mplication a much more extended area, a certain kind ridge is more or less evident wherever a small valley arger one.

'hese ridges are always found between the confluent , are crossed by the lesser stream, and are nearly parallel arger valley.

'hey sweep out into the main valley or across the mouth



–Drawing to show probable flow of ice currents from Lake Louise valley.

lesser one somewhat proportionally to the probable for- iensions of the glaciers occupying them.

'hey are of unstratified drift, whose upper ends rest a rock buttress between the confluent valleys.

They have a constant characteristic curve of outline, and zontal projection, the latter corresponding to what would lines of medial moraines on uniting glaciers from such nt valleys.

They are not sharp crested, but are evidently a subglacial

formation and their direction is not, like terminal or lateral moraines, influenced by minor topographic features.

From the foregoing it seems evident that these drift ridges are a subglacial formation disposed under the ice along the same lines as medial moraines would have had on the glacier surface, and that they are a kind of crag and tail formation resulting from the union of two glaciers. The fact that a rock buttress is the initial point of these drift ridges, shows that they were not the result of a short action at the close of the ice invasion. The change of all the preglacial V-shaped valleys to the present U-shaped form was accomplished by a great amount of erosion and transportation of débris. The rock ridges which commence and probably underlie the drift ridges are portions of the old V-shaped valleys which by their position have been preserved. They represent lines of protection from severe erosive action, and it is therefore necessary that the rock should be preserved along the same line in which the drift has been deposited. These lake basins are therefore possibly in many cases rock basins, but made much deeper by an overlying drift formation.

It remains to inquire why the glaciers from the tributary valleys did not cut out channels of even gradient, instead of leaving these basins. Thus the bottom of Lake Louise is 230 feet below the very lowest part of its dam, and the lower surface of its glacier must have ascended this slope upon entering the Bow Valley. A study of existing glaciers shows that a tributary is always narrower after confluence with a larger glacier as a result of the more rapid movement of the ice current. It is probable that this contraction takes place in the vertical dimensions as well as the horizontal, and thus causes the under surface to ascend, while of course the upper maintains its level.

WALTER D. WILCOX.

THE PIRACY OF THE YELLOWSTONE

Ever since the Grand Canyon of the Yellowstone was introduced to the general public, it has enjoyed a well-deserved fame for its grandeur and for the unrivaled beauty of its coloring. To the physiographer it has stood as a type preëminent of a very young river valley in the trench stage of development. All who have seen it have been profoundly impressed by it, and by many it is considered the most satisfying object of beauty in the region. It is now possible to introduce this already famous canyon in a new light, as the scene of one of the greatest acts of piracy on record.

The Yellowstone Lake, with an altitude of 7741 feet A. T., lies in a depression in the southeastern part of the great rhyolite plateau of the Yellowstone National Park. On the east of the lake the land rises rapidly to the high crests of the Absaroka range. On the north and west, and for the most part on the south, the land rises to the general level of the plateau, eight hundred to a thousand feet above the lake. North and south of the lake, and fringing the west shore, are considerable areas of flat land, not far above the present lake level and plainly lacustrine in origin.

The long southeast arm of the lake is seen to be the lower end of a magnificent mountain valley, here submerged. Beyond the lake the valley extends over thirty miles to the southeast, past the limits of the Park, up into the heart of the Absarokas. The upper Yellowstone River occupies this broad vale, at present wandering on a gradient which compels it to constant deposition, the flat bottom of aggraded material averaging over a mile in width for twenty miles southeast of the lake. This valley is manifestly very old, and it has its counterpart in the Lamar Valley in the northeastern part of the Park. It has been shown[1]

[1] Arnold Hague: The Age of the Igneous Rocks of the Yellowstone National Park, Am. Jour. Sci., 1896, I, p. 454.

that both these valleys were old and well developed before the rhyolites were poured out to form the Park plateau in Pliocene time. The lower courses of both these valleys are masked by the rhyolite flows, and the lake depression itself may be suspected to be a great mountain valley obstructed by lava flows.

The divide west of the lake lies on the flat-topped rhyolite plateau, and at various places there are cols of significant shape and altitude. Plainly some of them have been lines of drainage, showing that at some time water has flowed across the divide, making well-defined valleys. The stage road from the Upper Geyser Basin to the "Thumb," as the west arm of the lake is locally called, passes through one of these notches at the continental divide east of de Lacy Creek. It is rather a narrow valley, with walls perhaps a hundred feet high, cut right across the crest of the divide, yet flat-bottomed and at present marshy and undrained.

It is believed that this whole region has been covered with ice moving west from the Absarokas and north from the Tetons, and it may easily be supposed that in the unequal recession of the ice margin, obstructed drainage would give rise to overflow to the west, establishing channels that would be abandoned on a further recession of the ice. But there is one such channel which gives evidence of very long use even after the ice had left the plateau. This is a "windgap" between Overlook and Channel mountains at *D* in the map, page 263. Here a canyon with walls several hundred feet high cuts across the present divide, down almost to the contour of 7900 feet. Yet this surprising notch is poorly drained, puny streams starting from the marshy col and flowing to opposite oceans. The eastern one is an unnamed branch of Grouse Creek, the one to the west, called Outlet Creek, leads into the Heart Lake basin and so south to the Snake River. This notch has been recognized as a former outlet of the lake, and the fact is well known that the lake was once at this altitude, about one hundred and sixty feet above its present level. Lacustrine deposits are recorded on the United

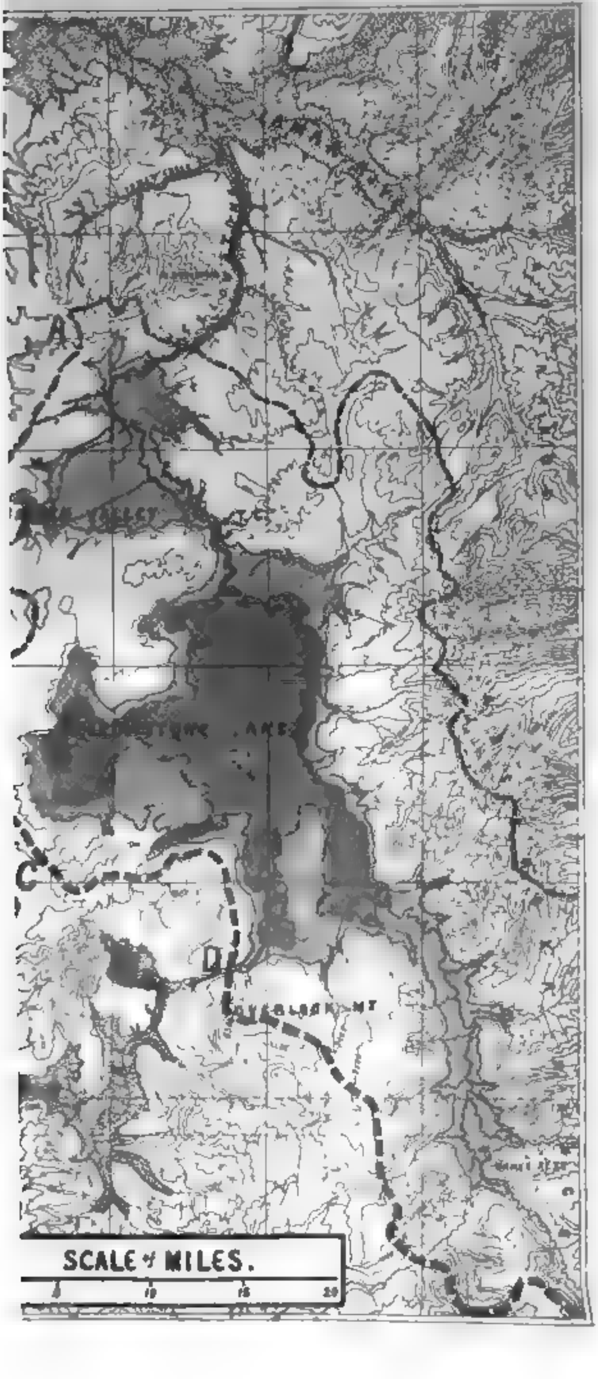


Fig. 1. Map of the eastern part of the Yellowstone National Park. The heavy dotted line C D is the present continental divide, the lighter line B A the ancient divide. The heavy hachured areas are present lakes, light hachured area is the ancient lake.

States Geological Survey maps,[1] practically up to the 7900-foo contour, all round the lake, and at its foot, to a point four mile below the present lake outlet, at Thistle Creek Canyon, marked T *C.* on the map, p. 263. At this level also are found terraces, ol sea cliffs and beaches, and while other shore phenomena ar found at lower levels, as, for example, at the sixty-foot leve yet in some respects the most strongly marked records are the higher level.

Through the Thistle Creek narrows to the north, the countr flattens down into the Hayden Valley—a triangular depression the plateau, ten miles east and west by seven or eight mil north and south. The surface of this depression is covere largely with moraine deposits of glacial drift, and all round th valley, particularly in the drift, the hills show a significant pr file, which, immediately below the Thistle Creek Canyon, undoubtedly terrace and sea cliff. On the upper courses Trout Creek, and across the river, east of Crater Hills, simil profiles are seen. The central portion of Hayden Valley is very flat plain, extending along the two streams, Alum and Tro Creeks. These two streams are wandering a very low gradient, Trout Creek showing beautiful an example of oxbows on a sm scale as may be found anywhere, and in wandering, its valley walls show stratifi clays, the fresh-cut bank in one place ne the roadway standing at a height of ov thirty feet against the stream (Fig. 2, *A*, *B*)

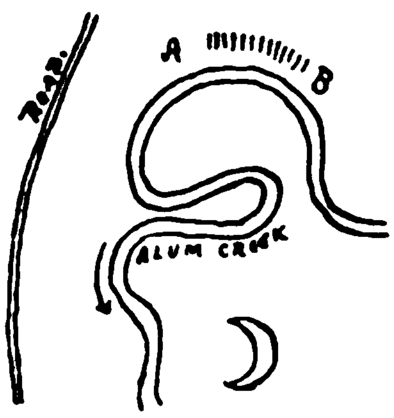


FIG. 2.

At the Grand Canyon the strongest impression one gets that the canyon is extremely young, that the river is still active corrading at bottom, and the walls all along are actively sloug ing, by every process of degradation. Yet this impression youth has its greatest emphasis, only when seen from the ea flank of Mt. Washburne. Here, at an elevation of about tw thousand feet above the plateau, the whole eighteen miles canyon is in view, from the Falls to Junction Butte, dwarfed no

[1] Yellowstone National Park Folio, U. S. Geol. Surv., Washington, 1896.

by distance into a simple roadside ditch. With this view, it is easy to see that the canyon is not all the same age. The north half of it is distinctly older than the south or upper half. In the north half the shoulders are markedly rounded, the walls less steep, the stream at bottom has long ago found an axial equilibrium with the material it has to handle, and is not deepening or widening its bed in any striking way. It is a surprise to notice, too, that Broad Creek, which empties into the Yellowstone River just at the east foot of Mt. Washburne, has a canyon every whit as wide, as deep, and with shoulders as rounded as has the main canyon at this point.

One cannot help wondering why the Yellowstone Canyon is so young only above this point; why the deep stratified clays in Hayden Valley; why the terrace and cliffs at the high level in Hayden Valley. Why did the Yellowstone Lake abandon a good outlet at Overlook Mountain, and flow off to the north? The explanation may be read from the correlation of the available data as follows.

The Yellowstone Canyon for five miles or so below the falls is extremely young, the occupation by the river representing only a fraction of postglacial time. On the recession of the ice from the region, the plateau of rhyolite stretched untouched by the river action, from the south base of Mt. Washburne southeast across the site of the present canyon, at the general plateau level of about eight thousand feet. There was no canyon, and no Yellowstone River there. The two depressions in the plateau, Hayden Valley, and the present lake basin, if they existed in preglacial time, outflowed by some other route, at present unknown. On the recession of the ice from the region, these basins overflowed to the west, over available cols. Possibilities of such drainage lines, besides the one mentioned on the road to the "Thumb," may be suspected at *A*, *B*, *C*, and *D*, on the map, Fig. 1. But the one which established itself for greatest permanence was the one described at Overlook Mountain.

Now taking the topographic map and supplying a shore line for a lake outflowing at this channel, the surprising fact is shown

that such a lake not only pushes itself into the great valley over sixteen miles to the southeast, but it goes on thru the narrows at Thistle Creek, on the very level of the terrace and sea cliff noted. It covers all the Hayden Valley, with the exception of the very peaks of Crater Hills, and extends on past the falls and the Canyon Hotel to Inspiration Point, thus making a great twin lake extending over fifty-one miles from Inspiration Point on the north to Hawk's Rest far down into the Absarokas on the southeast. This greater lake is shown in the map by the lighter shaded area. The darker shading showing the area of the present lake.

The only assumption necessary in this reconstruction, is the absence of any considerable crustal deformation in postglacial time, and so far as known there is no evidence of any appreciable change of this kind in the area during this time.

Let us look now at the character of the Grand Canyon as it appears among its neighbors. The dominant topographic feature of the northeast part of the park is the great Lamar Valley. It is over two thousand feet deep, and its walls have receded under the tooth of time until a broad and generous vale a mile and more in width at bottom extends for twenty-five miles above the point of its confluence with the Yellowstone River. This vale was old in the Pliocene. It was deep and of generous size before the rhyolites and basalts were poured out to mask the old drainage and make the plateau in which the Yellowstone Lake and Canyon now lie. Once see this great valley and the impression is inevitable that the Yellowstone Canyon is a very late comer. Moreover, as a canyon it is not of much more importance than its neighbor of Tower Creek on the west. In short, the Yellowstone Canyon, from Junction Butte back to the east flank of Mt. Washburne, is not the work of the Yellowstone River at all, but was made by Broad Creek, then a small tributary of the Lamar, of no more consequence than Tower Creek, which joined it from the west. Its canyon may have been begun in preglacial time, but long after the general ice-sheet had left the region it remained an obscure stream, slowly

FIG. 3. Map of the scene of the piracy, showing relative size of the canyons of ower Creek and Broad Creek. The contours of Broad Creek Canyon are supplied place of the upper half of the present Yellowstone Canyon.

pushing its growing gorge back into the rhyolite of the plateau.

In Fig. 3 the site of the future Grand Canyon is represented, the contours being copied from the U. S. Geological Survey topographic map, with the exception that south from the mouth of the present Broad Creek the contours of Broad Creek itself are supplied, in the line of drainage of Sulfur Creek. The col between the Sulfur Creek gorge and the greater lake lay about two miles north of Inspiration Point in the old Continental divide. Yet the Sulfur Creek pirate was a long time eating thru this two miles or so of barrier. And all this while—a good fraction of postglacial time—the great lake was giving its water thru the Overlook Mountain channel to the Snake River, and the beaches, terraces, and sea cliffs were building at the contour of 7900 feet—about 160 feet above the present lake level. In the Hayden Valley part of the lake, similar beach records were making, and the stratified clays were being deposited off-shore.

The rate of advance thru the col by the Sulfur Creek pirate would depend upon three factors, the volume and gradient of the stream, and the nature of the rhyolite. The volume of water was not large, being only the drainage from the south flank of Mt. Washburne and the east flank of Dunraven Peak. The gradient was high, about 1500 feet, in the Sulfur Creek branch alone, while the rhyolite in the path of the canyon was in admirable condition for easy working.

The rhyolite, on first cooling from its flow, was hard and firm of texture, the obsidian or volcanic glass being one phase of it, usually found at the surface. In deeper levels it may have been as hard and crystalline as basalt; but the hot vapors from below have attacked the firm rock and in many places totally changed its character, making the felspars over into kaolin and leaving the once firm lava a crumbling mass, almost like slaked lime. Yet this solfataric action has not been universal. It has worked very effectively in certain areas, while in other places the solid rhyolite has wholly escaped the decomposing action. Were this not so, the canyon would long ago have advanced clear to the present lake.

The trend of physiographic history in the region was sud-
enly changed when the col was cut thru by the advancing
anyon. The water of the lake began to flow out to the north,
ie increased volume very greatly hastening the deepening and
idening of the trench. The lake level was rapidly lowered,
ie Overlook Mountain outlet was suddenly abandoned, and
ith this change the continental divide was transferred to its
resent position south of the lake. The lowering of the lake
:vel was extremely rapid for a hundred feet, while the outlet
as cutting in the decomposed rhyolite merely. In the hundred
:et of rapid lowering but slight traces of shore action on the
ke could be expected. But this rapid lowering was checked
hen the river reached the 7800-foot contour, for it came upon
wall of firm, undecomposed rhyolite standing squarely across
s path—the site of the present Great Falls—and the river
:ttled down to the task of sawing this barrier in two. It is still at the task, with nearly a quarter of its work yet to do. This barrier is only about a hundred feet thick, and is very plainly marked in the brow of the canyon wall, forming a narrow gateway thru which the water rushes. The inner walls of this gateway are very precipitous, as may be seen in the familiar view of the Great Falls. Immediately above and below this gateway the canyon walls fall away to a wide V-shape in section. The plan, Fig. 4, shows the relation of the barrier to this fall, and
ow the canyon is narrowed to the precipitous gateway in the
arrier. As seen from the down-stream side, this barrier is evi-
ently cut down a little over half its height, and one may easily
onjecture that this fall, which is now 312 feet high, must have
arlier been much higher, perhaps even 700 feet. The present
row of the fall is near the up-stream face of the barrier, and
anding at the brow one may see that the firm rock of the bar-
er projects at the bottom on the east side of the stream, as a

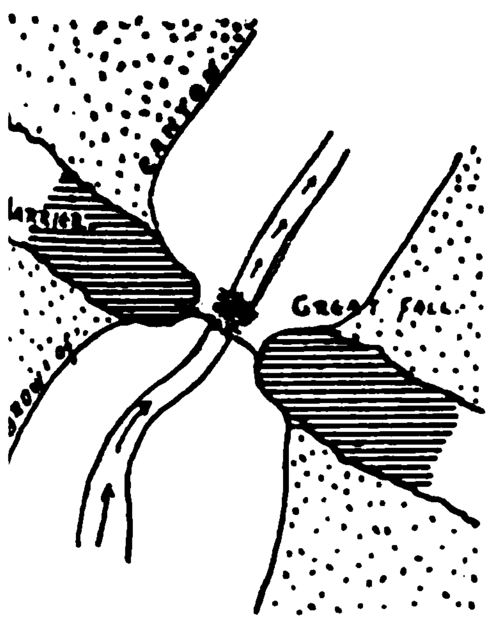


FIG. 4.—Diagram of the
rrier at the great fall.

shelving ledge upon which the water is ceaselessly po
shown in longitudinal section in Fig. 5. So this fall m
to be showing signs of old age—that is, the rapids
development has already begun.

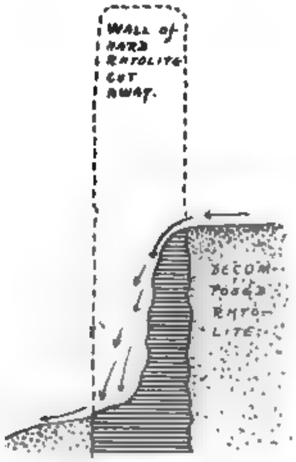


FIG. 5.—Longitudinal diagrammatic section of the great fall.

With the lake outlet ap
this barrier at the contour of
a current was formed at t
Creek narrows, and two sepa
resulted, with a short river
The lower lake, covering Ha
ley we may provisionally ca
Lake. The river at the na
glacial drift only to work o
competent to cut this out
Hayden Lake level followed
ing brow of the falls.

The problem was made n
plex when the river discovere
wall of firm rhyolite at the s
Upper Fall. This wall is mu
than the lower one, and the process of cutting is prop
slower. It was the lowering of this barrier which d
the lowering of Hayden Lake level. When the wa
somewhat below the 7700-foot contour, Hayden
drained, and this has only very recently been accompli
shown by the flat and sinuous course of Trout Creek.

The wearing down of the barrier at the Upper Fall
lagged behind that of the lower. It could not be touc
until the lower barrier was reduced below its level
height of the Upper Fall has always been limited at
level, by the brow of the Lower Fall. The Upper
increased in height almost uniformly with the de
height of the Lower Fall, and it is plain to be seen,
the Lower Fall has finally sawed thru its barrier,
will carry the canyon gradient back to the Upper Fall
then be perhaps four hundred feet high.

With the lowering of these two barriers, other barriers were uncovered in the path of the stream above. The most important of these is a ridge of firm rhyolite in the bottom of the Thistle Creek narrows. This became a large factor in the history of the Yellowstone Lake, when in the cutting of the canyon at this point, this firm rhyolite was reached, at a level about sixty feet above the present lake. The lake level since then has waited on the lowering of this one barrier. It is the only barrier which now determines the lake level, altho it seems plausible that in earlier stages, a barrier at Mud Geyser, and perhaps even the Upper Fall barrier, were agents also in maintaining the lake at the sixty-foot terrace, the action on each barrier being much deferred by the lack of gradient due to the former higher elevation of these lower barriers.

This is the postglacial history of Yellowstone Lake and Canyon as it may be read from the data in hand. The whole great lake, with its drainage basin of about fifteen hundred square miles, was captured by the little Sulfur Creek canyon, taken bodily from the Snake River and the Pacific slope, and added to the Lamar River and the Atlantic slope. And the volume of water in the captive stream was so great as to dominate the lower valley of the Lamar, and reduce that older stream to the rank of a minor tributary.

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THE FAUNA OF THE DEVONIAN FORMATION AT MILWAUKEE, WISCONSIN

THE best, and until recently, the only known area of Devonian rocks in Wisconsin lies immediately north of Milwaukee and furnishes the Milwaukee hydraulic cement of commerce. This rock, in the localities where it is exposed, is a limestone, rich in magnesia, alumina, iron and silica. The best known exposure is in the valley of the Milwaukee River, about half a mile north of the present city limits. At this point many acres of the rock are accessible, forming the bed of the river, and stretching away on either side under alluvial and drift deposits, the latter of which constantly increase in thickness with the distance from the river. The formation is here about twenty five feet in thickness. Its surface may be thirty feet above the level of the lake, which lies a mile and a half to the east. There is a slight dip towards the southeast. The formation rests upon a dark, porous limestone supposed to be of Lower Helderberg age, without fossils. Three miles further north, at the edge of Lake Michigan, is an outcrop which rises slightly above the water level, and is about twenty feet thick. A shaft sunk at this place discloses layers corresponding to those of the lower twenty feet of the quarry on the river. Five miles north of the latter and about three miles further west there is a third exposure in a railway cut, at a considerable height above the river which flows near by; but the deep drift in the neighborhood of the cut has prevented any determination of the extent of the formation in this locality.

Within the past five years it has been found necessary to make additional provision for the city's water supply. In carrying out this provision a shaft was sunk to a depth of one hundred and thirty feet at the edge of the beach at the head of North Avenue, and from the bottom of this shaft a tunnel was bored extending out thirty-two hundred feet under the lake. As a preliminary to this undertaking test bores were made at a num-

ber of points. One of these, at a point very near the place where the shaft was finally sunk, revealed the following section, as shown by the records of the City Engineer's office. At the depth of forty two feet below water level, black shale was found, underlying strata of sand, gravel, and red and blue clay; at fifty seven feet, "soapstone;" at ninety seven feet, cement rock; at one hundred and seven feet, "soapstone" again; at one hundred and thirty-eight feet, "brownstone and lime rock." The "brownstone and lime rock" was not penetrated to any depth and it is not possible, perhaps, to assert positively what it was; but it is believed to be the same as the Lower Helderberg rock underlying the cement rock on the river.

The material taken from the new intake shaft and tunnel was dumped indiscriminately upon the beach. It has since been spread out, covered with soil, planted with grass and trees and made into a park. It was impossible, for the most part, to sort out the different components of the mass, or to determine except in a general way their original order of superposition. Cement rock and "soapstone" were mingled with each other and are alike disintegrating and turning to clay. The "soapstone" is a lumpy, nodular shale of a greenish-gray color, soft, when wet, hardening into something very like rock when dry, and turning very rapidly to clay under exposure to the rain and air. It strongly resembles some layers of the cement quarry rock, whose lowest and highest layers possess much the same qualities. Portions of the soapstone carry fossils in an excellent state of preservation, of the same species, for the most part, as those found at the quarry on the river. Mixed in with the "soapstone" are very hard layers, from one to four inches in thickness, largely composed of shells of *Chonetes scitulus* Hall, of a gibbous form, associated with *Tentaculites bellulus* Hall. The same form of *Chonetes* is also found amid the softer material in the dump and in the lower division of the quarry. The *Tentaculites* is also found at the cement quarry, but not so abundantly. A distinctly flatter variety of the same species of *Chonetes* is found in other portions of the "soapstone," and in the upper layers of the quarry.

Finely preserved shells of *Spirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., the latter with coarse plications, are found in the "soapstone" and in the upper layers at the quarry. Other portions of the "soapstone" are almost, or wholly, devoid of fossils, and in this they resemble some of the softer layers near the bottom of the quarry.

In the mass dumped on the beach were found some large stones, having the appearance of bowlders, composed of hard rock similar in color to the harder cement rock, but traversed by very hard white seams of a siliceous character. These seams are full of fossils, most of which are also found at the quarry. Such are *Chonetes scitulus* Hall, of the gibbous variety, *Spirifer subvaricosus* H. & Wh., *Palaeoneilo fecunda* Hall, and many others. Associated with these, however, are a number of gastropods, which give a distinctive character to the fauna of these seams; gastropods, with the exception of *Platyceras*, being very rare at the quarry. Among the gastropods of the white seams are *Bellerophon* near *pelops* Hall, and species of Pleurotomaria, Cyclonema and Loxonema.

The black shale, mentioned above as the first rock formation penetrated by the intake shaft, is quite distinct from the other materials dumped on the beach. Pieces of it exhibit glacial scratches. Its only fossils are two or three species of *Lingula*. Certain layers are firm and smooth-grained; others are extremely fissile, splitting into thin, rough laminae. There is also a greenish shale, whose exact place in the series is not ascertainable, also carrying species of Lingula. These shales are not found anywhere else in place in the state, though small rounded pieces are not uncommon in the drift. They seem to have given way everywhere else under the erosive action of the glaciers.

The rock at the cement quarry on the river comprises two main subdivisions distinguished, to some extent, by differences in their fossils, but still more noticeably by the different states of preservation in which their fossils are found. The lower subdivision is twenty-one feet in thickness. Fossils are abundant in this division, but principally in the form of casts and

ıpressions. Almost the only ones which are well preserved are ɛcimens of *Lingula*, *Orbiculoidea* and *Conularia;* the plates, ales and teeth of fishes; and some plant remains in carbonized ɪrm. At the top of this section is a very hard layer about six et in thickness, containing cavities lined with crystals of calcite ıd pyrite. This layer is very rich in fossils, very few forms ing absent from it which are found in any part of the quarry; ıd it is especially distinguished by the multitude of its cephalopod ıd fish remains. The layers below this one are softer, some of ıem very soft indeed, and are on the whole less rich in fossils; ıt the surfaces of some of the lower layers are covered with ritized shells of brachiopods, mainly *Chonetes scitulus* Hall, of ıe gibbous form, and *Delthyris consobrina* D'Orb.

The upper subdivision comprises the upper four feet of the ıarry. Its surface has been smoothed by glacial action. Most its fossils are found as casts in the section below, but here the ıells are often preserved. Much of the rock of this division is a lumpy, nodular character, and suffers rapid disintegration ıder atmospheric influences, the fossils weathering out.

These two sections, at the lake and at the river, are not presely alike but are easily correlated with each other. The entire ries of Milwaukee Devonian rocks may therefore be convenntly subdivided as follows, the section at the water tunnel ing designated A, and the section at the cement quarries B.

A 4. The Lingula-bearing shales.

A 3. That portion of the "soapstone" carrying shells of *pirifer euryteines* Owen, *S. asper* Hall, and *Atrypa reticularis* L., ıd the flat variety of *Chonetes scitulus* Hall; being the upper soapstone" of the City Engineer's section.

A 2. This includes the thin hard layers so rich in specimens f the gibbous variety of *Chonetes scitulus* Hall, and *Tentaculites llulus* Hall. It also includes portions of "soapstone," probably he lower "soapstone" of the City Engineer's section, containing he same variety of *C. scitulus* Hall, and *Conularia*. Its relations eem to be with subdivision B 1 of the quarry rock.

A 1. This consists of the thin white seams, whose rel
are not definitely known.

B 2. The upper four feet of the quarry rock, correspo
with A 3.

B 1. The lower twenty-one feet of the quarry rock, i
ing the very hard six-foot layer and several softer and less
iferous ones. This corresponds with A 2.

Very likely subdivision B 1, at the cement quarry, co
still further subdivided, the exceedingly hard layer at t
being especially worthy of a place by itself. It is sufi
however, at present to say that this layer probably carries
fossils of the layers below it except the plants — which com
further down — most of those above, and in addition a
number of fossils peculiar to itself. Among the latter ar
of the fishes, most of the cephalopods, a few brachiopoc
many pelecypods.

In the following table an attempt has been made tc
together the fossils of the several subdivisions for purpo
comparison. The lists are not exhaustive. Even at the c
quarry, which has been the most thoroughly examinec
species are occasionally found. The faunas of the shal
"soapstone" are less perfectly known, owing to the l
opportunity afforded for their study. Yet the formati
already furnished in the neighborhood of two hundred s
a remarkably rich collection from so limited a territory.

The determinations of species are in some cases provi
The specimens of *Chonetes* and *Spirifer* have been submi
Professor R. P. Whitfield and Mr. Charles Schuchert. Tl
remains have been identified by Dr. C. R. Eastman a
crinoids by Mr. Stuart Weller. In other instances some
names may have to be changed. Some of the species a
and have not yet received names.

It will be noticed that some species which are mentio
the *Geology of Wisconsin* as coming from this formation a
contained in this list. Among them are *Chonetes co*
Conrad; *Productella spinulicosta* Hall and *Trematospira*

Hall, all of which were probably determined from imperfect casts, or may have been taken from erratic blocks wrongly supposed to have been derived from this formation. Others, like *Spirifer granuliferus* Hall, *S. audaculus* Conrad, *S. angustus* Hall, and *S. euryteines*, var. *fornaculus* Hall, were probably mistaken identifications, justified at the time, but based upon casts of *Spirifer euryteines* Owen, which here exhibits great variations of form. Shells of the last named species are rarely found at the quarry, and only in one or two places, not in the rock but in the soil above composed of disintegrated rock. They are quite abundant in the upper "soapstone" from the intake. It is not probable that any had been unearthed at the time of the publication of the *Geology of Wisconsin*. They are distinguished by clearly marked lines of fine striation.

The writers have not attempted the correlation of the Milwaukee fauna with the faunas of other localities, but leave that interesting task to more competent hands. The Spirifers of the list, however (*S. iowaensis* Owen = *S. pennatus* Owen; *S. asper* Hall; *S. euryteines* Owen = *S. parryanus* Hall = *S. capax* Hall; and *S. subvaricosus* H. & Wh.) show an obvious relation to certain Devonian faunas of Iowa. It is proper to state that the shell here identified as *S. subvaricosus* H. & Wh. was by Mr. Schuchert considered to be a primitive form of *S. bimesialis* H., another Iowa species. Professor Whitfield, however, considers the identification as *S. subvaricosus* to be correct. Specimens of the shell from B 2, in which the beak has been ground down, seem to show a median septum. So do the casts in B. The latter, however, do not generally show the strong plication of fold and sinus, and such have been identified as *Delthyris consobrina*, D'Orb. (= *S. ziczac* Hall.) There is in the list a little *Rhynchonella*, identified as *R. contracta*, var. *saxatilis* Hall, which, if properly named, belongs also to the Rockford and High Point faunas. The Milwaukee specimens of *Schizophoria striatula* Schl. (= *Orthis impressa* Hall) are a form with a wide and not very deep sinus. Occasional forms are found resembling *Schizophoria tulliensis* Vanuxem, and *S. macfarlani* Meek.

A partial correlation of the fish remains has been furnished us by Professor Eastman. It is as follows:

Dinichthys pustulosus, Eastman — Hamilton Group of Iowa, Illinois and New York; Upper Devonian of Iowa.

D. tuberculatus, Newberry — Chemung Group of Pennsylvania; Upper Devonian of Belgium.

Ptyctodus calceolus, N. & W.—Hamilton Group of Iowa, Illinois, Missouri, Manitoba; Upper Devonian of Iowa.

Heteracanthus uddeni, Lindahl— Hamilton Group, Buffalo, Ia.

Onychodus sigmoides, Newberry — Corniferous Group of Ohio and New York; Chemung Group, Delaware county, N. Y.

Acantholepis fragilis, Newberry — Corniferous of Ohio & New York.

Sphenophorus, sp. — Chemung Group of Pennsylvania (*S. lilleyi* Newb.)

NOTE.— In the following tables the position of the various species in the different subdivisions is indicated according to their relative abundance by the letter A, abundant; C, common; O, occasional; R, rare.

FAUNA OF THE MILWAUKEE DEVONIAN FORMATION

	A_4	A_3	A_2	A_1	B_2	B_1
PISCES						
fis fragilis Newb. (=*A. pustulosa* Newb.)					Occasional small fish remains	R
sp.						R
s pustulosus Eastman						O
ulatus Newberry						R
. . . . . .						R
thus politus Newberry						R
i Lindahl						R
s sigmoides Newberry						R
dus greenei Newberry						O
acanthus telleri Eastman						R
calceolus N. & W.						R
Eastman						R
lus excavatus Newberry						R
orus sp.						R
thys sp.						R
fishes, of undetermined species.						O
CRUSTACEA						
ris (=*Ceratiocaris*) sp.						R
rana Green					C	O
p.					R	R
. . . . . .				R		
CEPHALOPODA						
ras breviposticum Whitfield						O
mae Whitfield						O
st ten other species, large and small, in-						
g so-called "Horses' Hoofs," all from B_1						
s sp						R
erys Hall						C
or four other species						R
s, large, like *O. bebryx* Hall						R
slender				R		
r two other species					R	R
PTEROPODA						
a sp.		?	R		R	R
sp.				R	R	R
tes bellulus Hall			A	A		R
GASTROPODA						
on, near *pelops* Hall.						
a sp				R		
a sp.					R	
a sp.				R		
mia sp., minute, preserved in pyrites						R
rge					R	
s auriculatum Hall.					R	
atum Hall					R	
m Hall.					R	
other species					R	
warta, two or three species				R		

	A_4	A_3	A_2	A_1	B_2	B_1
PELECYPODA						
Actinopteria sp.				R		
A. sp.					R	R
Cimitaria elongata Conrad						R
Clidophorus oblongus Hall						R
Goniophora hamiltonensis Hall						R
Grammysia nodocostata Hall		R				R
G. subarcuata H.						R
G. sp.						R
Leda, near *rostellata* Conrad						R
Lyriopecten, near *interradiatus* Hall						R
Modiola precedens Hall						R
Modiomorpha affinis Hall						R
M. alta Conrad						R
M. concentrica Conrad					R	O
M. macilenta Hall						R
M. mytiloides Hall						R
M. ponderosa Hall						R
M. quadrula Hall						R
M. subulata Hall						R
M. subulata var. *chemungensis* Hall						R
Mytilarca umbonata Hall						R
M. (Plethomytilus) oviformis Conrad						R
Nucula corbuliformis Hall						O
N. randalli Hall						O
Nuculites oblongatus Conrad				R		
Palaeoneilo brevis Hall		R				
P. constricta Conrad				O	O	C
P. elongata Hall						R
P. emarginata Hall				R		R
P. fecunda Hall		O		O	O	O
P. plana ? Hall				R		R
P. sp.		R				
Paracyclas elliptica Hall				R		
P. tenuis Hall						R
Pterinopecten near *intermedius* Hall		R				
Sphenotus, near *cuneatus* Conrad						R
S., near *clavulus* Hall						R
Many other species of Pelecypoda, imperfectly preserved in B_1						
BRACHIOPODA						
Athyris fultonensis Swallow		R			A	R
A. sp.					R	
Atrypa hystrix, var. *occidentalis* Hall						O
A. reticularis L.		A	O	O	A	A
A. spinosa Hall						R
Camarotoechia near *sappho* Hall						R
C. contracta var. *saxatilis* Hall		R		R	R	R
Chonetes scitulus Hall — flat variety		O			A	
C. scitulus Hall — gibbous variety			A			C
C. vicinus Castelnau (= *C. deflectus* Hall)						R
Craniella hamiltoniae Hall						R

	A_4	A_3	A_2	A_1	B_2	B_1
ilineata White.					R	
nsis Hall.		R			A	R
nsis var. *recta* Hall.		R			C	R
sobrina D'Orbigny.				C		A
vini H. & Wh.					C	
blaeni Hall.					O	
kelloggi Hall.						O
...						R
...		R				
planata Williams.	R					
ll.						R
l.	C					
Vanuxem.	R					R
...						R
liformis Hall.						R
lodiensis Hall.		O			O	O
ar. *media* Hall.		O			O	O
Whitfield.		O			O	O
species.						R
...					R	
hemungensis var. *arctistriata* Hall.		O		R	O	O
, two species.						R
ta iowaensis Owen.		O			A	R
macfarlani Meek.					R	
chlotheim.		R			A	A
anuxem.					R	R
Hall.		C		R	O	O
yteines Owen.		C	R	R	O	A
Owen.					R	O
Atwater.					R	R
var. *posterus* Hall						R
us H & Wh.				O	A	O
...						O
demissa Conrad		O	R	R	A	A
Conrad.		O	R	R	A	A
...					O	O
one or two species					R	
OA — including Monticuliporoids						
o species, free growing					O	
o species on shells of Brachiopods.					O	
...						O
...						R
...					R	
e or two species on shells of Brachiopods					C	
mifusa Hall, on Gomphoceras.						R
mifera Rolle, on Gomphoceras						R
ie or two species					A	
sp., on shells of Brachiopods.						R
liporoids there are several different nd species; with simple thin-walled h thick walled cells, with intermediate ; massive, dendritic, and laminar - In , and B_2.						

	A_4	A_3	A_2	A_1	B_2	B_1
ANNELIDA						
Cornulites sp.					R	
Spirorbis, one or two species, on Brachipods					R	R
ECHINODERMATA						
Melocrinus milwaukensis, Weller					R	
M. milwaukensis var *rotundatus* Weller					R	
M. nodosus Hall					R	
M. nodosus var. *spinosus* Weller		R			R	
M. subglobosus Weller.					R	
M. sp.					R	
Pentremitidea filosa Whiteaves					R	
P. milwaukensis Weller					R	
Taxocrinus sp.					R	
Crinoid stems of several sorts					C	
COELENTERATA						
Favosites sp.						R
Heliophyllum halli Ed. & H.						R
Zaphrentis, one or two species						R
SPONGIDA						
Sp. ?						R
PLANTAE						
About a dozen carbonized forms of land plants of several genera; some threadlike, or with threadlike branches; the largest over four feet long and as much as five inches wide; all somewhat flattened, mainly in the softer layers of B_1.						
Also several species of fucoids, in all layers of both sections.						

As we go to press, Dr. C. R. Eastman, furnishes the following note on the fossil fishes mentioned in the foregoing article:

ELASMOBRANCHS

Ptyctodus calceolus N. & W. (Tritors only).

P. ferox East. (Complete dental plates, upper and lower jaws).

Rhynchodus excavatus Newb. (Complete dental plates, upper and lower jaws).

Palaeomylus greenei (Newb.). (Complete dental plates, upper and lower jaws).

Cladodus sp. nov. (Detached teeth).

Heteracanthus politus Newb. (Spines).

H. uddeni Lindahl. (Spines).

"PLACODERMS" (including *Arthrodira*)

Acantholepis fragilis Newb. (=*A. pustulosa* Newb.). Fragmentary spines).

Phlyctaenacanthus telleri Eastm. (Fragmentary spines).

Dinichthys tuberculatus Newb. (Fragments of dermal armor).

D. pustulosus Eastm. (Crania, dorsal and ventral plates; also portions of the dentition).

Large, thin plates belonging to two as yet unknown Dinichthyids, probably *Dinichthys* or possibly akin to *Titanichthys*.

Sphenophorus sp. nov. (Fragments of dermal plates).

CROSSOPTERYGIANS

Onychodus sp. (Clavicle and other plates very suggestive of *O. sigmoides* Newb., but as yet no teeth nor scales, sufficient to prove specific identity).

Several varieties of scales and other fragments.

CHARLES E. MONROE.
EDGAR E. TELLER.

MILWAUKEE, WIS.
February 16, 1899.

THE PETROGRAPHICAL PROVINCE OF ESSEX COUNTY, MASS. IV.

BASIC DIKES

By far the greater part of the dikes of this region are dense black rocks, evidently very basic in character. The majority of these are diabases of various kinds, only a few not belonging to this ever-present family and representing more unusual types. However, these basic dikes have been so far but little investigated, but it will not be amiss to describe the specimens in my possession.

Camptonitic dikes.— Cutting the foyaite of Salem Neck and, according to Sears, the "augite-syenite" of Coney Island in Salem Harbor are dikes of dense, black, finely crystalline rock without phenocrysts, and composed essentially of hornblende less augite, and plagioclase. These rocks are unlike typical camp tonites since there are no large and abundant ferromagnesian phenocrysts, and alumina is rather high. In certain respect they seem to be allied to the proterobases. They are provision ally classed with the camptonites for various reasons, among which may be mentioned their connection with foyaite, certain features of their chemical and mineralogical composition, and their resemblance to camptonitic rocks from localities in Maine New Hampshire, Vermont, and Norway. It is, by the way, a somewhat remarkable fact that no typical camptonites or mon chiquites have yet been observed in the region.

Under the microscope these rocks are holocrystalline, and i fresh specimens have a structure approaching the ophitic, thoug the colored components are, as a rule, more automorphic than i the case when this structure is typically developed. The fo lowing minerals are present: much hornblende, less pyroxen occasional olivine, plagioclase, a little orthoclase, some magne tite, and rare apatite. Neither biotite nor titanite were seen

ie hornblende forms either stout prismatic crystals or irregular ains. In the latter case it is generally, but not constantly, er than the plagioclase and interstitial to some extent. It is peculiar yellow-brown, closely similar to the barkevikite of : Norway rocks, as shown by comparison with sections of ese. The pleochroism is strong: for the axis nearest *c*, dark llow-brown; parallel to axis *b*, about the same, nearly parallel axis *a*, light greenish-yellow. The depth of the color ren-red the determination of the axes of elasticity uncertain. The tinction is rather high, about 20 degrees. This hornblende quently occurs as a primary border about augite and magne-:, as in the hyperitic diorites. The pyroxene, which forms egular grains or occasionally large porphyritic crystals, is orless, with sometimes a tinge of green or violet. Olivine is e, except in one specimen from Coney Island, in large cor-led colorless grains. They are usually altered at the borders a black granular substance, and are occasionally serpentinized. e plagioclase, which occurs in long lath-shaped sections, tabu- parallel to *b* (010), as well as in anhedra, is highly twinned. easurements by Michel-Lévy's method indicate a labradorite :h the composition $Ab_3\ An_4$, though some are nearer the desines. Small colorless interstitial grains with low refractive lex are referred to orthoclase.

	I	II	III	IV
SiO_2	46.59	48.98	45.20	48.08
TiO_2	1.41	0.56	0.68	2.57
Al_2O_3	17.55	17.76	17.12	16.95
Fe_2O_3	1.68	2.14	5.98	4.78
FeO	10.46	6.52	6.55	7.60
MnO	.....	.....	.....	trace
MgO	7.76	2.09	5.29	5.51
CaO	10.64	8.36	7.89	7.79
Na_2O	3.31	6.77	4.23	3.37
K_2O	0.72	2.08	2.31	1.42
H_2O (110°)	0.10	.....	.....	.....
H_2O (ignit.)	0.07	4.50	5.35	0.80
P_2O_5	.....	.....	.....	0.63
CO_2	....	0.82	.....	.....
	100.29	100.58	100.60	99.48

I. Camptonite (?). Salem Neck. H. S. Washington anal.
II. "Diorite-Porphyrite." St. Johns, N. B. W. D. Matthew, Trans. N. Y. Ac Sci., Vol. XIV, p. 213, 1895.
III. Camptonite. Portland, Me. E. C. E. Lord, Amer. Geol., Vol. XXII, 344, 1898.
IV. Bronzite-Kersantite. Hovland, Norway. Brögger, op. cit., Vol. III, p. 75.

An analysis of a fresh specimen from a narrow dike cutti foyaite on Salem Neck is given in I. The low titanium oxi accords with the absence of titanite and the character of tl pyroxene. It is evident that alumina largely replaces ferr oxide in the ferro-magnesian minerals. This is a feature c barkevikite as shown by Flink's analysis,[1] and some of the horr blendes whose composition has been calculated by Brögger,[2] a well as of the hornblende of Hawes's camptonite.[3]

As was stated above very similar rocks have been observe in New England. For instance, it resembles a specimen fror Livermore Falls, near Campton, N. H., for which I am indebte to Professor Pirsson. This, however, does not carry hornblend phenocrysts, and is also like some of the camptonites of Lak Champlain.[4] Hobbs[5] also describes similar rocks as augite diorite, occurring in connection with the diabase of Medfor Mass. A nearly identical rock is described by W. D. Matthew as occurring in dikes near St. Johns, N. B. The hornblende also apparently barkevikite, and an analysis of this rock is give in II. Very recently E. C. E. Lord[7] has described a dike camptonite from Portland, Me., which is closely allied, and th analysis of which is given in III. These two contain conside ably more alkalies than those described in this paper. The:

[1] DANA, A System of Mineralogy, New York, 1892, p. 403.

[2] BRÖGGER, op. cit., III, p. 110.

[3] LORD, Amer. Geol., Vol. XXII, p. 343, 1898; also, ROSENBUSCH, Elem. Ge lehre, p. 234, No. 1, 1898.

[4] KEMP and MARSTERS, Bull. U. S. G. S., No. 107, p. 29, 1893.

[5] W. H. HOBBS, Bull. Mus. Comp. Zoöl., Vol. XVI, p. 10, 1888.

[6] W. D. MATTHEW, Trans. N. Y. Acad. Sci., Vol. XIV, p. 210, 1895.

[7] E. C. E. LORD, Amer. Geol., Vol. XXII, p. 342, 1898. *Cf.* KEMP, dikes n Kennebunkport, Me., Amer. Geol., p. 129, 1890.

are all decidedly more acid than the usual camptonites, and carry higher alumina. Chemically they show marked affinity with certain kersantites from Norway described by Brögger,[1] one of his analyses being given in IV.

Vogesitic dikes.—A few dikes were found of a dark rock composed of hornblende, augite, and biotite, but with alkali-feldspar very largely predominating over plagioclase. A little quartz is also apt to be present, which is apparently primary. These rocks then have the mineralogical composition of vogesite or minette, apart from the presence of quartz, and are provisionally put here, since no chemical analysis has yet been made of them.

As an example there may described a dike from Davis Neck, Cape Ann, which is almost black, fine-grained, and compact, and with small shining black phenocrysts of ferro-magnesian minerals. Of these the pyroxene is colorless or very pale green, the hornblende of a light bluish-green, both in irregular grains, and the biotite in thick plates of a light brown color and highly pleochroic. These minerals are not distributed evenly, but occur in streaks in which one or the other predominates. The interstitial groundmass is of colorless granular alkali-feldspar without plagioclase or quartz. A little magnetite is present but no apatite.

Diabase.—Dikes of dense black rock, which may be grouped under this heading, are very abundant. They far outnumber all the other dikes put together, but as is usually the case they are rather monotonous in character, as well as nearly always more or less altered. Shaler's map of Cape Ann will show their abundance, and to his paper[2] the reader is referred for a full discussion of their occurrence, dip and strike, and other features. As regards their relations to the other rocks it may be noted that they cut, and are hence later than, all the other types.

They vary from fine-grained to aphanitic, the usual change in texture from center to border being often seen. In general they are not as coarse-grained as the sheets, dikes, and flows of

[1] BRÖGGER, op. cit., Vol. III, p. 71

[2] SHALER, Ninth Ann. Rep. U. S. G. S., 1889.

similar rock which are met with in such abundance in the Triassic of Connecticut and New Jersey, this being due to their having cooled as much smaller bodies. Amygdaloidal structure is very rare. They may be divided roughly into two main groups, the ophitic and basaltic, though these merge into each other, and frequently the center of a dike is ophitic while its border is basaltic.

The ophitic diabases present the usual features. The feldspar, in stout plates, is chiefly a well-twinned plagioclase, with extinction angles corresponding to a labradorite of about the composition $Ab_1 An_3$. It is often cloudy or epidotized through alteration. A little orthoclase seems to be present. The augite, which is seldom automorphic, is pale violet-gray in thin sections, and is frequently uralitized, often to such an extent that little of the original mineral remains. Magnetite is quite common in large grains, often showing octahedral outlines, and has a strong tendency to stout skeleton growths. An interesting case of this is seen in a dike-cutting rhyolite on Marblehead Neck where the magnetite skeletons assume the form of small stout crosses with thickened ends, or with their ends joined by the sides of a hollow square, the cross in this case forming the diagonals. These growths are analogous to those of leucite in certain leucitites from Montana[1] and Italy.[2] The magnetites are frequently accompanied or surrounded by brown, apparently secondary, biotite, even in the freshest specimens. With this exception neither biotite nor hornblende is to be seen, nor was olivine observed. Apatite is not abundant.

The basaltic diabases are black and aphanitic, without megascopic phenocrysts. They show in thin sections laths of clear labradorite and some crystals of augite in a mixture of augite grains, small labradorite laths and magnetite with considerable light-brown glass base. The magnetite very frequently assumes delicate arborescent forms, branching at right angles, which are very pretty and characteristic. In a small apophysis of the

[1] L. V. PIRSSON, Bearpaw Mountains, Am. Jour. Sci. (4), Vol. II, p. 145, 1896.

[2] H. S. WASHINGTON, Bolsena, JOUR. GEOL., Vol. IV, p. 557, 1896.

ophitic Dike 73, at Bemo's Ledge, Cape Ann, magnetite is wanting and the brown glass abundant. Flow structure is sometimes seen. These varieties closely resemble many normal olivine-free basalts.

	I	II	III	IV	V
SiO_2	47.12	48.75	51.78	51.36	36.85
TiO_2	3.27	0.99	1.41	....	....
Al_2O_3	14.43	17.97	12.79	16.25	15.46
Fe_2O_3	3.33	0.41	3.59	2.14	....
FeO	11.71	13.62	8.25	8.24	17.50
MnO	....	0.91	0.44	0.09	....
MgO	6.05	3.39	7.63	7.97	5.60
CaO	9.63	8.82	10.70	10.27	15.73
Na_2O	2.58	1.63	2.14	1.54	....
K_2O	1.11	2.40	0.39	1.06	....
H_2O (110°)	0.28	....	....	....	....
H_2O (ignit.)	0.34	0.60	0.63	1.33	....
P_2O_5	....	0.6[illegible]	0.14	....	....
	99.85	100.17	99.89	100.28	91.14

I. Diabase. Rockport. H. S. Washington anal.

II. Diabase. Medford, Mass. Sweetser anal. Traces of CO_2 and FeS_2. Probably Al_2O_3 too high and MgO too low. Hobbs, Bull. Mus. Comp. Zoöl. XVI, p. 9, 1888.

III. Diabase. West Rock, New Haven, Conn. G. W. Hawes anal. Proc. U. S. Nat. Mus., IV, p. 132, 1882.

IV. Diabase. Watchung Mountain, Orange, N. J. L. G. Eakins anal. Bull. 48 U. S. Geol. Surv., p. 80, 1897.

V. Diabase (?). Marblehead Neck. R. Pearce, Proc. Colo. Sci. Soc., IV, 1893.

For purposes of analysis the freshest specimen was chosen from a dike of ophitic diabase cutting the granite in the large quarry pit at Rockport. It calls for little remark, except that the alumina is rather low and the titanium oxide is high. It resembles analyses of other diabases from Massachusetts, one of which is given (II), but is more basic than the "traps" of Connecticut and New Jersey (III and IV). For purposes of completeness a partial analysis is given (V) of a so-called diabase dike, briefly noticed by R. Pearce, from Marblehead Neck. It is not very satisfactory. The silica is abnormally low, lime high,

as well as iron oxides, and the large loss is difficult to account for, assuming that the analysis is correct. There cannot be enough alkalies to make up the deficiency, and it is probably largely water. The rock is possibly decomposed, since Merrill[1] has shown that diabase loses silica through decomposition. It is also possible that it is a monchiquite.

Labradorite-porphyry.—Closely related to the diabases are a few dikes distinguished by the presence of prominent phenocrysts of plagioclase in a black, fine-grained groundmass. The best example is Shaler's Dike 175, which cuts across the quarry pit at Pigeon Cove. It is eighteen feet in width, with a strike of N. 9° W.[2] The phenocrysts here are very large and automorphic. A similar dike cuts the tinguaite at Pickard's Point, in which the phenocrysts at the center are even larger, attaining diameters of more than six inches; toward the borders they are smaller, and at the contact very small.

The groundmass of these rocks is like that of the diabases, though an ophitic structure is less often developed. It is composed of labradorite, augite, and magnetite, primarily, but in every case is more or less altered, so that secondary hornblende and biotite with chlorite, etc., are present in abundance, and any analysis would be unsatisfactory.

EXTRUSIVE ROCKS

Rhyolite.—The only flow rocks found in Essex county are rhyolites, which occur in large sheets about Lynn, Newbury, Old Town, and Marblehead Neck. The last is the only locality which I have visited. This is not the place to dwell upon the discussions which have taken place as to the origin of these rocks, between Sterry Hunt and his followers, who tried to show that these, as well as all the igneous rocks of the region, were altered sediments, and the other party, headed by Wadsworth and Diller, who finally overthrew this view and proved conclusively that they are typical volcanic flows. For particulars of this discus-

[1] G. P. MERRILL, Bull. Am. Geol. Soc., Vol. VII, p. 349, 1896.

[2] SHALER, op. cit., pp. 592, 607.

ion the reader is referred to "The Azoic System," by Whitney nd Wadsworth.[1]

These rhyolites are dense, black, aphanitic rocks, with a dull or subvitreous luster and subconchoidal to even fracture. Small, white feldspar phenocrysts are scattered through this black groundmass. A banded or flow-structure is often noticeable, and is especially well brought out on weathered surfaces.

Under the microscope these rocks present a somewhat monotonous appearance. The feldspar phenocrysts are usually quite sharply automorphic, less often fragmentary. Most of these are of orthoclase, or rather soda-orthoclase, while a few show the twinning lamellæ and extinction angles of oligoclase-albite. They are all somewhat decomposed so that optical examination is unsatisfactory.

The groundmass is composed of alkali-feldspar with some finely granular quartz, very small shreds and grains of pale greenish pyroxene and a little magnetite. Glass is present in some specimens, but in the majority of cases it has been devitrified, and its former presence is difficult to determine with certainty. Some of the specimens were apparently primarily holocrystalline. Flow-structure is observed, but is not as marked as one would be led to expect from some of the weathered specimens. These rhyolites, it may be added, are accompanied by ash beds and breccias.

I owe to Mr. Sears a specimen of a dike rock much like these rhyolites, which cuts the diorite on the south shore of Salem harbor, west of Marblehead. It shows flesh-colored feldspar and colorless quartz phenocrysts in an aphanitic groundmass. In thin section it resembles the rhyolites, but is distinguished by the abundance and sharp outlines of the quartz phenocrysts and the presence of numerous spherulites in the devitrified groundmass, which exhibit a black cross between crossed nicols.

[1] Bull. Mus. Comp. Zoöl., Vol. VII, Cambridge, 1884, pp. 331–565. *Cf.* also G. H. Williams, Jour. Geol., Vol. II, p. 24, 1894.

SiO_2	70.64	MgO	0 52
TiO_2	0.90	CaO	1.24
Al_2O_3	15.34	Na_2O	5.23
Fe_2O_3	1.83	K_2O	3.55
FeO	1.10	H_2O (110°)	0.14
MnO	trace	H_2O (ignit.)	0.38
			100.87

Rhyolite. Northeast coast of Marblehead Neck. H. S. Washington anal.

For the analysis a typical specimen was chosen from the northeast coast of Marblehead Neck. As will be seen, these rocks are rather acid, and resemble the quartz-syenite-porphyry more than they do the aplite. The only point to be mentioned here is that soda is considerably higher than potash.

Keratophyr.—The last rock to be described is that by which this region is, perhaps, best known, which Rosenbusch[1] has taken as the type of his bostonites, and which Sears[2] has described as keratophyre. Accepting provisionally Rosenbusch's system of classification the choice of names depends on whether the rock occurs as a dike or a flow. Owing partly to the fact that the exposure is only visible at low tide the relations are somewhat difficult to make out. My observations were confirmatory of the views expressed by Wadsworth[3] and Sears[4] that the rock forms a flow and not a dike, overlying rhyolite and conglomerates. This being so, I think that the name bostonite is not justified in this case, and I prefer to retain Sear's name, keratophyr (rather than trachyte), on account of the large content of anorthoclase, even though this name is in several respects a very bad one.

My specimens come from Boden's Point, below Mr. Foster's house, and from below the Corinthian Yacht Club House. Although the rock has been described by Sears and Rosenbusch, a few words may be devoted to it. The freshest specimens are

[1] ROSENBUSCH, Tsch. Min. Pet. Mitth., Vol. XI, p. 447, 1890; Mikr. Phys., Vol. II, p. 467, 1896.

[2] SEARS, Bull. Mus., Comp. Zoöl., Vol. XVI. p. 167, 1890.

[3] WADSWORTH, Proc. Boston Soc. Nat. Hist., Vol. XXI, p. 288, 1881.

[4] SEARS, op. cit.

white, weathering to brown, very fine-grained and with a
er, and a tendency to schistosity, which largely accounts
earlier view that this was a sandstone. A few glistening
henocrysts of anorthoclase are visible.
hin section the phenocrysts show the characters described
nbusch and Sears. The groundmass is trachytic with
ced flow-structure, and is composed largely of small
ldspar laths, these being generally clear. The interstitial
is clear and colorless with low refractive index, partly
c and partly feebly doubly refracting. Some of it seems
ass and some kaolinized feldspar. There is considerable
and many small black and brown specks, the remains of
ferro-magnesian minerals, which, however, never were
in a large amount Very few traces of these remain,
e, small biotite flakes being seen. A little quartz is pres-
is rare.
analyses of this keratophyr are given, one by myself
other by Dr. Chatard, of the United States Geological
for Mr. Sears. They resemble each other very well,
mine shows a little more silica. It will be noticed that
not markedly different from the rhyolite, though in this
higher.

	I	II
SiO_2	71.40	70.23
TiO_2	....	0.03
Al_2O_3	14.76	15.00
Fe_2O_3	1.68	1.99
FeO	0.72	....
MnO	trace	0.24
MgO	0.55	0.38
CaO	0.10	0.33
Na_2O	4.79	4.98
K_2O	5.16	4.99
H_2O (110°)	....	0.91
H_2O (ignit.)	1.46	1.28
P_2O_5	....	0.06
	100.62	100.42

I. Keratophyr. Boden's Point, Marblehead Neck. H. S. Washington anal.

II. Keratophyr. Boden's Point, Marblehead Neck. T. Chatard anal. Sears, Bull. Mus. Comp. Zoöl., XVI, p. 170, 1890; also Bull. 148, U. S. Geol. Surv., p. 78, 1897.

HENRY S. WASHINGTON.

EDITORIAL

THE great success which has attended the application of hotography to the determination of the positions and move- ients of stars may well stimulate geologists to attempt a similar pplication to earth movements. It is a not uncommon belief mong mountaineers that peaks which were formerly not visible om certain points of view have recently come into sight, and onversely that points formerly in view have disappeared from ght. There is nothing incredible in this if warping is in active rogress, and it would seem worthy of being put to the test of xact observation. It would not be difficult to take photo- raphic panoramas from selected points of view, and to record ith precision the positions of the camera, so that views could e taken from exactly the same points at subsequent dates. A omparison of such views would serve to show whether any ppreciable warping of the crust is in progress or not. The ffect of degradation on the one hand, and of snow accumula- ion, on the other, could easily be eliminated, and the influence f refraction might be avoided by taking the photographs in recisely similar conditions of atmosphere and light, or the roper correction could be made. As this method is probably pplicable only to serrate alpine tracts, it is to be hoped that ome of the geologists of those regions will interest themselves o far as to take and duly register a first series of photographs o that comparison may be made at some future time.

T. C. C.

THE doctrine of alternate quiesence and readjustment of the ust of the earth serves such a radical function in the inter- etation of ancient peneplains, sea-shelves, and epicontinental as, and in the elucidation of expansional, repressional, and pro- icial epochs of life evolution, that a precise conception of what

is understood by quiescence and readjustment may aid in the removal of doubts and objections, since some of these seem tc be based on a rather too rigid and literal interpretation of th terms quiescence and readjustment and their synonyms. Lik most terms which relate to the mutual relations of the sea an the land, or of the continental platforms and the abysmal basin the term quiescent has a merely relative meaning. It does n necessarily signify an absence of absolute movement toward tl center of the earth, but simply an absence of *differential* mov ment relative to other portions of the crust. If the whole cru sinks toward the earth's center at an equal rate in all its par the relations of the continental platforms and the abysmal basi remain essentially undisturbed and may be said to be quiesce Such a shrinkage may theoretically reduce the capacities of t ocean basins just as it reduces the whole surface of the sphe and this reduction of basin capacity may cause the sea to ov lap the margin of the land in some degree. But this incursi of the sea, would, if appreciable, be justly regarded as only incident of the quiescent stage. It would indeed be only one several factors involved in that transgression of the sea which so characteristic of quiescent stages. It is only when suc common sinking of the crust toward the center develops *differ tial* stresses of such magnitude as to require a notable warpi crumpling, or faulting of the crust that the relations of the co tinental platforms to the abysmal basins are seriously distur and the quiescent stage is replaced by one of readjustment. is perhaps even necessary to regard such a common centripe movement during the quiescent period as a necessary anteced of the period of readjustment, for such a movement is perh necessary to develop the differential stresses out of which readjustment springs. All objections therefore to the doctr of periodic quiescence which are based upon the conceptior the absence of centripetal motion should be set aside as ba upon misconception. The only valid theoretical objections those which apply to the conception of periods of *concor* centripetal movement alternating with periods of *discordant* c

tripetal movement. The former are quiescent periods so far as the relations of platforms and basins are concerned, the latter are periods of readjustment. The dynamical conception involved in this view is somewhat radically different from that involved in the literal conception of quiescent periods as periods of no crustal movement at all.

In the accumulation of the general stresses which issue in general readjustments, local stresses of special intensity must almost necessarily be developed and these may reach such a degree of intensity as to lead to local readjustments. These local readjustments may result in the distribution of the stresses over wider areas, and these wider areas may in time yield and transmit the stresses to still broader fields until the stresses become general and reach such a degree of intensity as to issue in a general readjustment. Local readjustments in the form of local warpings and faultings may be incidents of the general quiescent stages, and like them may be essential antecedents of general readjustments involving the formation of mountain systems and similar pronounced phenomena.

T. C. C.

THE DUPLICATION OF GEOLOGIC FORMATION NAMES

THE custom of giving more or less local geographic names to geologic subdivisions has become so universal that we are even now duplicating the use of such names to a considerable extent. Geological literature is of too great bulk for the working geologist to attempt to ascertain whether or not names which he proposes to use have been preoccupied. To illustrate what the present system is leading to a few instances of some prominence will be cited.

In 1883 Hague described, in a report of the United States Geological Survey the Eureka quartzite, a subdivision of the Silurian in the Eureka district, Nevada. In 1891 Simonds and

Hopkins, in a report of the Arkansas Geological Survey, us the name Eureka shale for a supposed Devonian horizon; wh in 1898 Haworth, in a report of the Kansas Geological Surv proposes the name Eureka limestone as a subdivision of the C Measures.

In 1879 Peale, in the Eleventh Annual Report of the Uni States Geological and Geographical Survey of the Territor employed the term Cache Valley group for a subdivision of Pleistocene of Utah. Becker described in 1888 the Cache L beds of California, in Monograph XIII of the United Sta Geological Survey, and referred them to the Tertiary. In 1 G. M. Dawson, in a report of the Canada Geological Surv uses the name Cache Creek formation for a horizon of Carboniferous to include strata described by Selwyn in 1872 Upper and Lower Cache Creek beds.

In 1842–1846 Emmons, Vanuxem and Mather employed term Erie division as a subdivision of the New York syst In the Ohio Geological Survey reports the Erie clay was u as a subdivision of the Pleistocene, and Erie shale was refer both to the Carboniferous and Devonian. In 1875 Les described, in a report of the Pennsylvania Geological Surv the Erie shale, which he referred to the Silurian. In 1 Haworth described the Erie limestone of the Coal Measures Kansas. The above references are given merely to illust the confusion that is likely to arise from the use of new g graphic terms if the literature is not carefully examined previous use.

For the past eighteen months the writer has been enga in preparing a card catalogue of geologic formation names, (ing such time as could be taken from other office and field w This catalogue has already assumed considerable proporti and is now being consulted by those geologists who are aw that such a work is being prosecuted. While preparing annual bibliography of geological literature for 1898 the wr has found several instances of duplication of names that h become well established in geological nomenclature. It

probably be a year or more before this catalogue can be published, and, in the meantime, to assist in avoiding such duplication, the writer offers to furnish geologists, who will correspond with him, such information as he possesses, regarding names which they propose to use as formation names.

F. B. Weeks.

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REVIEWS

Experimental Investigation of the Formation of Minerals in an Igneous Magma.[1] A review.

Professor Morozewicz has at length published in German the results of five years' elaborate experimentation on the synthesis of minerals and of volcanic rocks. This work is the most exhaustive of its kind since Fouqué and Lévy's epoch-making experiments, published in Paris in 1882. The wide scope and large scale of the experiments of Morozewicz, and the very complete chemical investigation of his products, together with carefully devised reference to the geological application, make this new work worthy of extended review and of careful study by geologists.

The motive of the experimenter was primarily to imitate, as nearly as possible, natural igneous magmas, and by fusion of carefully prepared chemical mixtures in a large glass furnace to produce crystalline masses in sufficient volume for isolation and chemical investigation of the component artificial minerals. The author lays stress upon the importance of more careful work in the chemistry of the silicates in mineralogy, and the chemistry of silicate mixtures or solutions in petrography. For the former the work of Lemberg and Thugutt is quoted as of primary importance, and for the latter Lagorio and Vogt have initiated methods of research that should be emulated for more complete understanding of the nature of igneous rocks. The work of Fouqué and M. Lévy was limited to microscopic investigation of the products of fusion in small platinum crucibles in the Fourquignon furnace. Morozewicz obtained the use of a corner in a large Siemens furnace, in a glass factory near Warsaw; the interior of this furnace is much of the time at white heat and continuously so for periods of weeks and months. The furnace is heated by a blast of carbonic monoxide mixed with air, and the temperature to which the crucibles were sub-

[1] JOSEF MOROZEWICZ (Warsaw). Experimentelle Untresuchungen über die Bildung der Minerale im Magma. Tschermak's Mineralog. u. Petrogr. Mittheilungen, Bd. XVIII, H. 1–2–3, pp. 1–90 and 105–240, 8 Plates, 1898.

jected was estimated to vary from 1600° down to 500° C. Two openings, half a foot long each, were arranged in the side of the furnace so that crucibles could easily be inserted and removed. The temperature within the entrance chamber was much less than in the heart of the furnace, and by placing a crucible first in the innermost glow, then at the inner mouth of the chamber, and lastly, a short distance within the chamber, conditions of gradual cooling and crystallization could be brought about. From day to day at certain periods there were variations in the temperature of the furnace itself due to the requirements of glass manufacture which went on as usual in the huge crucibles of the factory, and these changes affected to a certain extent the crystal structures obtained. Fire-clay crucibles of various sizes were used, the melting being done in large crucibles, the crystallization in smaller ones of 150 c. c. capacity. The crucibles when filled were carefully covered and placed on refractory tiles. They were first warmed to dark red heat and then thrust into the position of maximum temperature. After a few hours they were drawn to the second position at the inner mouth of the opening, and finally, after remaining there for several days were drawn within the small chamber where they finally cooled.

Crystallization lasted commonly from one to three weeks, but in exceptional cases the crucibles were left in the furnace as long as two and one half months. A few experiments were made on a very large scale in the great factory crucibles where over a hundred pounds of mineral matter was molten at a time. It was found that certain mixtures corroded the crucible violently, while others remained unaffected by contact with the crucible walls. Magmas with high magnesia and low alumina and alkalies acted violently upon the clay, because magnesia has, at these high temperatures, a very strong affinity for alumina, and in the absence of alumina from the mixture combines readily with that which forms the containing vessel. Mixtures of lime and the alkalies, rich in alumina, do not affect the crucible, even after long exposure to the highest temperatures. About two hundred experiments were made in all, and of these 25 per cent. failed owing to various causes. The others produced coarsely crystalline mineral masses in many cases, so that isolation of the minerals for analysis could be accomplished. The mixtures used were prepared usually from pure chemicals Silica was used in the form of the hydrate $SiO_2.3H_2O$; alumina as hydrargillite ($Al_2O_3.3H_2O$); lime, magnesia, and the alkalies as carbon-

ates, iron oxide as hematite, and instead of ferrous iron was used either siderite ($FeCO_3$) or a fayalite-slag (Fe_2SiO_4).

The pulverized substances were intimately mingled and at first carefully heated to drive off the water. For the larger and coarser experiments common commercial mixtures were used, but in all cases the proportions were calculated as nearly as possible with reference to the known composition of igneous rocks. For a special group of experiments, combinations of minerals in theoretical proportion were prepared, in order to test the theory of solutions; the rock-forming silicates are conceived as capable of supersaturation of a magma, and, in proportion to their relative amounts and the nature of the solvent, crystallize out in the order of saturation; all the mineral products were carefully analyzed and the results were checked in each case by carefully sampled quantitative analysis of the mixture *after fusion*, in order that the effect of the addition of new silica or alumina from the crucible walls, by corrosion, might be allowed for. Finally, a special group of experiments involved the melting up of pieces of natural rocks, granite, andesite, basalt and others, and these experiments the author is still carrying on.

The following list will show the great variety of minerals produced by so-called "dry fusion" from silicate magmas:

1. Oxides: Corundum, Hematite, Ilmenite, Quartz, Tridymite and a peculiar prismatic variety of SiO_2.

2. Aluminates and Ferrates: Spinel, Chlorospinel, Pleonast, Hercynite, Magnoferrite, Magnetite.

3. Silicates: Sillimanite, Cordierite, Olivine, Forsterite, Fayalite, Monticellite, Enstatite, Hypersthene, Augite, Alkaline Augite, Pleochroic green Augite, Diopside, Wollastonite, Biotite, Lepidomelane, Sanidine, Labradorite, Anorthite, Melilite, Nepheline, Haüyne, Nosean, Sodalite, and Lagoriolite.

The following volcanic rocks were artificially produced: Rhyolite with flow structures, spherulitic basalt-obsidian; enstatite-basalt with both intersertal-glassy and micro-porphyritic structures; normal basalt with micro-porphyritic structure; augitite with hyalopilitic groundmass; melilite-basalt in both micro-porphyritic and granular forms; and haüyne rocks of intersertal-glassy and granular structures. From mixtures supersaturated with alumina were produced mineral aggregates bearing abundantly crystalline Al_2O_3 in the form of corundum and related minerals. Among these were a cordierite-andesite of glassy o

micro-porphyritic structure, and ophitic spinel-basalt, a spinel-bearing feldspathic basalt of micro-porphyritic and divergent-radial structure; a corundum-bearing nepheline-basalt, melilite-basalt bearing spinel; corundum-nephelinite, and coarsely trachytic corundum-bearing anorthite-nepheline mixtures.

Corundum and spinel have frequently been obtained synthetically by both "wet" and dry methods, and an examination of the literature, no less than the casual production of these minerals in preliminary experiments, showed that an excess of alumina readily induces the crystallization of free Al_2O_3, in the form of corundum, and with relatively high magnesia and iron in addition, produces spinel. The minerals were isolated and analyzed; both green and black varieties of spinel were obtained, the one chlorospinel, the others pleonast and hercynite. A comparison of the magma analyses with the relative amounts of these minerals produced, shows that alumina plays the principal rôle in the production of spinel as well as corundum. On the hypothesis that the crystallization of free alumina indicates supersaturation, it was believed that precise saturation, or the condition of the magma after the excess of Al_2O_3 had crystallized out, should give a ratio of alumina to the bases of 1 : 1, that being a constant in most of the aluminosilicates (feldspar, nepheline, haüyne, sodalite, mica, etc.). This was confirmed by eight analyses of the glass from which the corundum and spinel had crystallized; these gave the ratios

$(K_2O-Na_2O-CaO):Al_2O_3:SiO_2 = $ (1b) 0.9:1:1.9; (2b) 0.9:1:2.3; (3b) 0.9:1:2.3; (4b) 0.9:1:2.3; (5b) 0.9:1:2.3; (6b) 1.2:1:1.9; (7b) 1.1:1:3.4; (8b) 1:1:3.2.

Thus with variable silica, the ratio of Al_2O_3 to the bases averaged = 1.

To confirm this result a special series of test mixtures were melted up and crystallized. These tests, made variously with magmas of the composition of basic and acid feldspars, with the alkalies and silica in varying proportions, and under varying conditions of cooling, gave the following important results:

1. A silicate magma is saturated with alumina, when the ratio of the bases to alumina is equal to 1.

2. Saturated aluminosilicate magmas of mixed composition and of varying silica contents, are capable at high temperatures of dissolving alumina and forming supersaturated solutions.

3. Pure soda-aluminosilicate magmas dissolve alumina in large

quantities; lime-magmas in small quantity and pure potash-magmas are, under the same conditions, incapable of dissolving alumina in excess.

4. Supersaturated aluminosilicate magmas, whether of mixed silicates or simple, with the general composition $MeO.mAl_2O_3.nSi\ O_2$($Me = K_2$, Na_2, Ca, $n = 2 - 13$), throw out all the excess of alumina (over $m = 1$) in the form of corundum crystals, when magnesia and iron are absent, and *n* is less than 6; in the form of sillimanite (or sillimanite and corundum) when *n* is greater than 6; in the form of spinel (or spinel and corundum) when the magma is rich in magnesia and iron and *n* is less than 6; or in the form of cordierite (or cordierite and spinel) when Mg and Fe are present and *n* is greater than 6. In the last two cases sillimanite and corundum may also sometimes crystallize out.

5. The amount of spinel or sillimanite, from magmas rich in magnesia or silica, depends wholly on the excess of alumina present. The same is also true of corundum.

6. The crystallization of corundum and spinel depends, not on the "basicity" of the magma, but only on the ratio of the bases (K_2O, Na_2O, CaO) to alumina. In the experiments, corundum crystallized out from magmas varying in silica from 0 (sodic-aluminate) to 13 (Rhyolite).

7. Rules 4 and 5 are not wholly true for those magmas which contain basic non-aluminous silicates like augite and olivine in any considerable quantity.

8. Corundum, spinel, sillimanite, and cordierite crystallize from silicate magmas according to the general laws governing crystallization from solutions.

In nature, magmas with alumina in excess occur, but are not very common. There are numerous cases of the primary occurrence of corundum, spinel, sillimanite, and cordierite in both plutonic and volcanic eruptives. The development of these minerals about inclusions and by contact metamorphism in clay slates is well known. These four minerals form a genetic group of close affinity in mode of origin. In the Urals there are numerous orthoclase-corundum rocks classed as pegmatites and syenites. Morozewicz describes fully a new type of great interest to petrographers, and of especial interest in connection with his experiments; the new rock he names Kyschtymite after the Kyschtym district in the Urals: it consists of a medium-grained mix-

ture of idiomorphic corundum of pyramidal habit, with anorthite and biotite, and accessory dark green spinel of earlier generation than the corundum, with also apatite and zircon.

A number of remarkable experiments were made with acid magmas of the general composition of rhyolite or granite. By dry fusion at high temperatures it has frequently been demonstrated that tridymite is a more stable form of crystalline silica than quartz. In the case of the partial fusion of a quartzose block of granite, the quartz became transmuted into an aggregate of shingly tridymite flakes, and the same has been noted in nature in inclusions of granite in a porphyry. The presence of alumina in an acid magma was found to prevent crystallization, where a non-aluminous silicate mixture partially crystallized in the form of tridymite and prismatic silica (the latter of the unusual type described by Fouqué and M. Lévy). Vogt, in his exhaustive studies of furnace slags,[1] has called attention to the influence of alumina in "retarding" the crystallization of a glass or a slag, and this fact is well known to glass workers who add alumina to prevent the development of silicate crystals. With the aid of the theory of solutions, this influence is easily explained; in general, supersaturated solutions give large crystals, a lower degree of saturation gives small crystals, and unsaturated solutions under the same conditions develop no crystals at all. Alkaline silicate magmas are capable of dissolving alumina in large quantities; alumina possesses for the alkalies and more especially the alkaline earths a very strong chemical affinity, forming with them very stable and widespread natural compounds. Accordingly alumina in small amount dissolved in such a magma has only the effect of uniting with a portion of the bases in potential aluminosilicate form, and preventing them from crystallizing out as simple silicates which in the absence of alumina would easily saturate the solution. Morozewicz has demonstrated that a very large amount of alumina is required to saturate a solution to the effect of permitting crystallization of the aluminosilicates, as outlined above. When great excess of alumina is present, however, crystallization may be readily induced. Thus the expression, "retarding crystallization," is applicable only to access of alumina up to the critical point of saturation, beyond this its effect is that of an accelerator. The effect, in fine, of a small amount of alumina in a glass, is to produce aluminosilicate

[1] VOGT, J. H. L.: Beiträge zur Kenntnis der Gesetze der Mineralbildung in Schmelzmassen und in den neovulcanischen Ergussgesteinen, Christiania, 1892.

molecular combinations, without saturation, and solidification takes the form of Van t'Hoff's "solid solution," namely an amorphous glass.

Rhyolite and trachyte magmas, with the Al_2O_3 percentage varying from 6 to 20, were fused in large masses under varying conditions, of cooling and for periods of a fortnight or more, solidifying invariably as structureless glass; the same magmas, it will be remembered, with an excess of alumina, developed the minerals of the corundum group with the greatest ease. The attempts were repeated with fluorides and phosphates added, but again without result. Finally success was obtained by adding 1 per cent. of tungstic acid to a rhyolite mixture of the following composition:

SiO_2	77.9
Al_2O_3	12.0
FeO	1.3
CaO	0.8
MgO	0.13
K_2O	3.3
Na_2O	4.6

A completely homogeneous glass was formed by the first fusion in the hottest part of the furnace, and partial crystallization was obtained by leaving the crucible at the inner mouth of the entrance chamber for fourteen days—a temperature estimated to vary between 800° and 1000° C. A heterogeneous mass showing flow structures resulted, yellow and white streaks alternating with bands of gray glass. In the microscope the white zones proved to be aggregates of myriads of bipyramidal quartz microlites, of hexagonal form, extinguishing parallel to the vertical axis, and optically positive. The yellowish streaks were much more abundant than the white, and proved to be composed of hexagonal plates of biotite of very perfect form and showing the truncated edges of the combination: (001) (111) $(1\bar{1}1)$ (011). The absorption scheme, pleochroism, color, extinction and double refraction all agree with the properties of biotite. Many of the crystals show corrosion phenomena. Finally abundant aggregates of transparent prisms were observed, sometimes in spherulitic grouping, with extinction usually parallel and occasional twinning. These were believed to be sanidine. There were some other indeterminate colored grains and spicular crystals. The groundmass was essentially an isotropic glass, but showed a spicular microfelsitic structure. There had thus been reproduced by "dry fusion," with the aid of tungstic acid, an association

of the essential minerals of granite—quartz, mica and acid feldspar. The influence of the tungstic acid the author believes to be as follows: after the temperature in the first melting has passed 1000°, neither tridymite nor quartz can form, because at these high temperatures the silica unites with alkalies to form a silicate, in which the tungstic acid is absorbed; it is believed that on lowering the temperature (the position of crucible which ultimately produced crystallization) the absorbed tungstic acid has the effect of decomposing these alkaline silicates and liberating the silica to form q1artz. It is not known what compounds the tungstic acid finally forms. Dr. Morozewicz objects strongly to the use of the term "mineralizer," and considers that much harm has been done to the progress of synthetic mineralogy by attributing all obscure reactions to the "mystical action of a mineralizer." He insists that "agent minéralisateur" has no scientific meaning and should be banished from the vocabulary of the mineralogist. This would seem a little unreasonable, in view of the fact that he himself acknowledges that his only success in obtaining crystallization of the granitic minerals was due to the action of a small amount of tungstic acid, which he explains by what at best is only an incomplete hypothesis. Modern petrographers have not ascribed any "mystical" power to the compounds of tungsten, zirconium, boron, fluorine, etc., but have observed that these elements are minor but invariable accompaniments of the crystallization of coarse acid pegmatites. Morozewicz has only added confirmatory evidence from synthesis of the actual importance of these agents to promote crystallization in an acid magma, and whatever they be called, their influence, whether chemical or physical, cannot be denied. Possibly the word "crystallizer" would be more exact than "mineralizer." It is certainly true, on the other hand, as Morozewicz points out, that this latter word has been much abused, and simple reactions have been allowed to pass unexplained as due to the action of a mineralizer, because a fluoride or a borate chanced to be in the equation.

The accompanying plates are reproduced to show the coarseness of crystallization obtained with basic magmas. The basic magmas are those still capable of dissolving free alumina, or, in other words, unsaturated. An enstatite basalt was produced from a mixture of three parts olivine, three parts labradorite, and one part augite. A large mass of this material was fused, a smaller quantity being separated for fusion with iron oxide (hematite) alone, the principal mass having a little

charcoal added to reduce the hematite present to the ferrous condition.

The smaller portion, after crystallization for twenty days, gave a well crystallized yellowish-brown mass. Pyroxene crystals could be seen with the naked eye. In the vesicles of the slag were remnants of unmelted hematite, as well as newly crystallized hematite flakes and brilliant spicular pyroxene crystals, sometimes 1^{mm} long. These crystals showed distinct prismatic, pinacoidal and pyramidal faces, pleochroism, and parallel extinction. In thin section, as shown in Plate IV, Fig. 2, distinct porphyritic structure was observed, with idiomorphic enstatite and olivine in a groundmass consisting of monoclinic pyroxene, plagioclase, magnetite, and a small quantity of glass. The olivine was in short crystals, completely transparent and colorless, of very strong double refraction and parallel extinction. The greater part of the olivine crystallized in spherical concretions. The plagioclase of the groundmass showed twinning with extinctions varying from 10° to 27°, hence, a labradorite. Its crystallization was earlier than the other components of the groundmass. The augite formed aggregates of prisms partly as small phenocrysts, but principally in the groundmass. The order of crystallization was thus olivine, enstatite, monoclinic pyroxene, labradorite, magnetite and augite, glass. The larger mass (over 100 pounds), gave also an enstatite basalt (Plate IV, Fig. 1) with crystals of both orthorhombic and monoclinic pyroxene, and olivine, in a colorless groundmass. This groundmass appeared to be a completely homogeneous colorless glass. Pieces of this glass, heated three days at the temperature of red glow without melting, acquired a trachytic crystalline habit of rough surface, and lost their original glassy luster. The groundmass by this heating, developed a crystalline mixture of tiny plagioclase and augite microlites, showing that long continued application of heat to a supersaturated solution, even in solid condition, could bring about crystallization. In order to test the temperature necessary to produce crystallization, the following experiments were devised. Six crucibles were filled with fragments of this slag and placed in a row between the hottest part of the interior of the furnace and the middle of the entrance chamber. At the end of a month it appeared that the innermost four crucibles contained only glass, which had strongly corroded the crucible walls; while in the fifth and sixth crucibles (those within the chamber) crystalline products had formed. An investigation of preparations from these crucibles showed that the order of crystallization of the component minerals was the same

throughout and forms a constant function of the chemical composition of the magma. Period of crystallization and temperature have an important influence only on the structure of the resulting rock.

The second plate here reproduced (Pl. VII) shows the products of crystallization from an anorthite-nepheline magma without magnesia, consisting principally of corundum, anorthite, and nepheline. This was fused in large masses, producing a well crystallized gray rock. In the microscope the principal mineral is seen to be plagioclase prisms in long rectangular form with distinct cleavage and multiple twinning. Between the plagioclase laths is a groundmass consisting of nepheline, magnetite and glass. The physical properties of this plagioclase are essentially those of anorthite (An_6 Ab_1) with the following chemical composition:

SiO_2	46.5
Al_2O_3	34.6
CaO	17.3
Na_2O	1.6

Corundum is enclosed in the plagioclase in the form of circular plates. The groundmass contains many small microlites of magnetite, forming sometimes a rectangular network. Nepheline occurs in short, hexagonal prisms and irregular masses, forming the greater part of the groundmass. There are, in addition, pleochroic yellowish corroded crystalline flakes, which are probably lepidomelane. The glass base occurs in variable quantity in different parts of the crucible.

The systematic subdivision of aluminosilicate magmas, in relation to these experiments, deserves especially thorough examination. The greater part of known eruptives on the surface of the earth belongs to the aluminosilicate group of magmas. The principal and most stable components of magmas are silica and alumina, while the bases are variable and easily replace each other to form both minerals and rocks. Both SiO_2 and Al_2O_3 are capable of crystallizing out in free form by supersaturation, and both (according to the experiments of Thugutt[1] and the theoretical conception of Wernadskij[2]) are capable of playing chemically the part of acids. Silica and alumina are thus conceived to have an analogous systematic significance in the classification of eruptive magmas, granite being a magma supersaturated with silica, and

[1] St. Thugutt, Zur Chemie einiger Alumosilicate. N. J. f. M., 1895, B.-Bd. IX,

[2] W. Wernadskij, Ueber die Sillimanitgruppe, sowie die Rolle der Thonerde in Silicaten. Moscow, 1891 (Russian).

corundum-syenite a magma supersaturated with alumina. Aluminosilicate magmas are thus divided into two great analogous groups, each of which is subdivided into three types, as follows:

GROUP A

1. Magmas supersaturated with Al_2O_3.
2. Magmas saturated with Al_2O_3.
3. Magmas not saturated with Al_2O_3.

GROUP B

1. Magmas supersaturated with SiO_2.
2. Magmas saturated with SiO_2.
3. Magmas not saturated with SiO_2.

In both groups type 2 is the same, a syenite or trachyte magma, simultaneously saturated with both alumina and silica. There are thus five principal types in all, as follows:

1. Magma supersaturated with alumina: corundum-syenite, bearing alkaline feldspars, and kyschtymite bearing lime-soda feldspars.

2. Magma supersaturated with silica: granites, rhyolites, quartz-diorites, dacites, etc.

3. Magma saturated simultaneously with alumina and silica: mica-syenite, trachyte, mica-diorite, and mica-andesite. In this magma the aluminosilicates are the essential minerals. The pure metasilicates and orthosilicates are accessory or absent.

4. Magma not saturated with alumina: gabbro, basalt, diabase pyroxenite and other basic rocks. Obviously this magma is also not saturated with SiO_2.

5. Magma not fully saturated with SiO_2: elaeolite-syenite, phonolite, leucitite, etc.

The magma types 4 and 5 are not identical. A biotite-elaeolite-syenite can be saturated with Al_2O_3 and not fully saturated with SiO_2. In the same way some nepheline rocks may be considered as saturated with Al_2O_3, but do not contain sufficient silica to develop free quartz. In the above scheme it is of course obvious that the rocks belonging to the first type of Group A are least widespread according to our present knowledge of the geology of the earth, and will be discovered, in the opinion of the author, in greater quantity in the future.

It will be seen that in these experiments all the essential minerals of the "neovolcanic lavas" have been reproduced with the exception

blende, and also many rock structures of characteristic habit. tructures are proved to be the result of external conditions of zation and also of chemical composition, both in qualitative ıntitative sense. The order of crystallization of the individual s depends on no one factor, such as "fusibility" or "acidity," the result of a complex equation in which, perhaps, the most nt element is the ratio of the quantities of the several com- dissolved in and composing the solution. One and the same ınd can begin to crystallize out sooner or later than another ng to the amount which is present. The order of crystalliza- different in different magmas, and different substances have dif- capacity for forming saturated solutions in an aluminosilicate In certain cases temperature has an important influence: ite, for instance, forms a saturated solution best at temperatures 1000° C. At higher temperatures it crystallizes out after Anorthite crystallizes out more easily at a higher tempera- er 1000°). The process is obviously much complicated by the in the magma itself as a solvent, by progressive crystallization compounds composing it.

following are a few of the principles defined by observations is date; but final laws of silicate saturation can only be attained y experiments of character similar to these, which, as in the d synthetic work of organic chemistry, shall have thrown light structural formulae and atomic relationships of the silicates.

Corundum, spinel, sillimanite, and cordierite in magmas super- d with alumina, are the first products of crystallization. Spinel imanite crystallize before corundum.

Magnetite at a temperature below 1000° crystallizes out in pro- to the supersaturation of a solution with ferric iron and to the of other iron compounds. It crystallizes sometimes before and nes after augite and plagioclase according to their relative s.

The different orthosilicates of the type Me_2SiO_4 (olivine, etc.) ize first from a magma not supersaturated with alumina.

Rhombic pyroxene develops earlier than augite, if the molecular magnesia (and ferrous iron) to lime is about three or more.

The crystallization of augite is very variable.

In a magma with haüyne (33 per cent.) in excess of anorthite cent.) the haüyne crystallizes first.

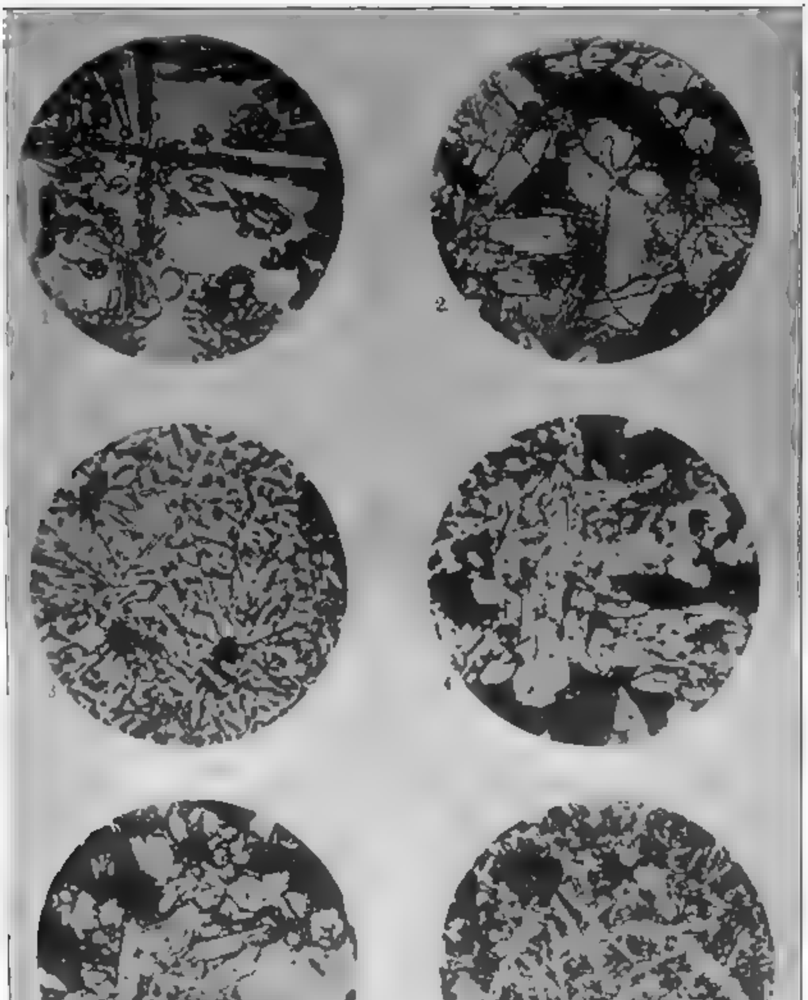
7. In a magma with the ratio of bases to alumina greater than 1, melilite crystallizes after olivine and simultaneously with anorthite.

8. Plagioclase begins to crystallize after olivine, and in many cases after augite, according to the amount present. Nepheline is one of the latest products of crystallization, forming usually a groundmass product between plagioclase laths (mesostasis).

10. The glassy groundmass represents an uncrystallized solid solution and frequently has the composition ($MeO.2SiO_2$) of Lagorio's "normal glass."

With respect to the question of magmatic differentiation, Morozewicz favors rather the hypothesis of one primary magma, chemically differentiated for a single region by means of processes determined in the main by the laws which govern solutions. In many of the experiments described a single crucible showed remarkable variations in structure, coloring, and composition locally. This was especially true of magmas rich in the alkaline earths. In a 100-pound mass, consisting chiefly of alkaline augite, the lower portion showed throughout a higher specific gravity than the upper, with much magnetite below and none above. In common glass-melting, separation of layers of higher specific gravity in the bottom of the crucible has been noticed, these being especially rich in iron, lime, and magnesia. A mass of granite weighing two pounds was melted in large pieces in the hottest part of the furnace, and allowed to glow at the inner entrance of the chamber for five days, producing a glassy mass below with quartz grains unmelted and partially altered to tridymite above. These quartz grains had apparently been floating in the glass; the glassy portion appeared fully homogeneous and was of uniform color; in fact, however, careful separate analyses of the upper and lower portions of the glass showed not only that the upper portion was richer in silica, but that the ratio of the bases was different. Thus Fe_2O_3 showed in the lower layers an increase of .8, MgO of .7, CaO of .4, and alumina of .2. The specific gravity of the lower part was about .1 greater than the upper. The silica percentage of the upper part was 73.65, of the lower part only 59.20. Thus the iron and alkaline earths settled to the bottom, and the silica and alkalies remain in excess above. It is significant that these substances (FeO, MgO and CaO) which form the lower stratum of glass, are the ones which crystallize out earliest from silicate magmas.

In conclusion the reviewer would call the attention of geologists



SYNTHETIC EXPERIMENTS BY MOROZEWICZ

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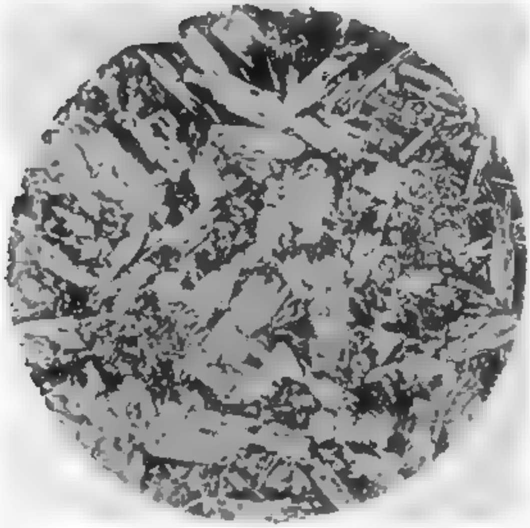

2

SYNTHETHIC EXPERIMENTS BY MOROZEWICZ

d petrographers to the accompanying plates reproduced from this markable monograph, and to the importance of careful study of the sults of such experimentation in connection with research in the field. r. Morozewicz has written the results of his elaborate synthetic studs in most compact and readable form, the work being contained in 5 pages systematically arranged, well indexed, with each chapter refully summarized as well as the whole work. He has shown that e synthetic production of rock-making minerals is possible under nditions attainable in any of our large cities, and his work should be stimulus to further endeavor of the same sort. Analytical work alone no more capable of solving many difficult problems connected with e origin of the igneous rocks and of ore deposits than are the meths of microscopical petrography. Morozewicz has shown that the me synthetic treatment is applicable to the chemistry of the silicates at has been used for years in the case of the hydro-carbon compunds.

T. A. JAGGAR, JR.

CAMBRIDGE, MASS.

PLATE III.

Fig. 1. Enstatite-basalt, first stage: olivine, enstatite, monoclinic pyroxe, glassy groundmass; enlarged × 60.

Fig. 2. Enstatite-basalt, second stage; micro-porphyritic structure: large statite crystals in a groundmass which consists of augite, labradorite, oline, and magnetite; enlarged × 60.

Fig. 3. Normal basalt, first stage; augite and magnetite microlites in assy groundmass (hyalopilitic); enlarged × 60.

Fig. 4. Normal basalt, second stage: great augite masses with inclusions f olivine and magnetite; brown groundmass; enlarged × 60.

Fig. 5. Enstatite-basalt: olivine concretions seen below; enlarged × 60.

Fig. 6. Basalt without olivine, ophitic structure: long plagioclase prisms ith augite in the interspaces; black grains of spinel and magnetite; nlarged × 60.

PLATE IV.

Fig. 1. Anorthite-nepheline magma: large anorthite crystals with cleavage cracks and multiple twinning; in the groundmass occurs nepheline, arborescent magnetite forms, etc.; ordinary light, enlarged × 15.

Fig. 2. The same between crossed nicols in polarized light.

Physical Geography of New Jersey. By ROLLIN D. SALISBURY: with an appendix by CORNELIUS CLARKSON VERMEULE. Being Vol. IV of the Final Report of the State Geologist. 8vo. pp. xvi + 170 — 200. Trenton. 1898.

New Jersey has set a good example for her sister states in the character and quality of the physiographic work set forth in this volume. Other states have made an enviable record in other lines of geologic work, but this is the first complete treatment of the physiography of a state we have had in America: and it is all the more notable for having as its author a specialist in physiography of the highest ability.

The plan of the work is, first, a plain statement of the facts of topography in detail, in the three natural topographic regions of the state, and second, the history of the topography.

The State of New Jersey, as a whole, is a part of the Atlantic slope, and though it is only 166 miles long, by about 40 miles wide, it includes portions of all the natural sub-provinces of this slope, *i. e.*, the coastal plain, the Piedmont plateau, and the Appalachian zone. Professor Salisbury shows that to this series another term should be added for the area under consideration, the series then reading from northwest to southeast; (1) *Appalachian* zone, of folded strata; (2) the *highland* area, of crystalline schists; (3) the *piedmont plain*, of Triassic rocks; (4) the *coastal plain*, of Cretaceous and younger strata, this last division covering a little more than the southern half of the state.

The members of this series all have their boundaries practically parallel with the Atlantic Coast, and as they differ widely in the nature of the materials from which they are built, the structure furnishes the natural basis for the division into zones, the topography being of the greatest importance in the interpretation of the geology. These four successive zones have a general slope to the southeast, directly across the structural boundaries, the inner or Appalachian zone having an average altitude of over 1500 feet, while the outer or coastal plain nowhere rises above 400 feet, by far the larger part of it being below 100 feet.

The Appalachian zone consists of early clastics, much folded, the axis of folding being northeast and southwest. Erosion has hollowed out broad valleys in the softer materials, and has left the harder beds standing up as long ridge-like mountains.

The second or Highlands area, made up of crystalline schists, does

'e topographic regularity which the structure has imposed inner zone, yet it has a deal of relief, being made of block-tain masses, flat-topped, of nearly equal elevation, nowhere peaks, and separated by rather broad valleys, so giving an ent of two or three ranges of hills with the general northeast-t trend.

third area, the Piedmont plain, has an undulating surface, to southeast, yet interrupted by conspicuous ridges, one of nts the Hudson as the Palisades. These ridges are outcrops nd represent dikes or flows of igneous rock.

coastal plain is coincident with the Cretaceous and later

In the description of all these zones, plates are given, show-is cross-sections drawn to scale, very helpful in getting a clear n of the actual topographic conditions.

such a complex structure, erosion has ever been busy, and by ential erosion, and deposition, a basis is given by which the ng attitude of the land is put on record. This very complex rofessor Salisbury and his assistants have deciphered for the e of geologic time since the Triassic, so a tolerably con-story is given us from the beginning of Cretaceous time, and nd downs on record in this area give a very vivid conception tability of the earth's crust or the ocean level, or both.

was a post-Triassic uplift when the Schooley peneplain was then a Cretaceous subsidence and considerable deposits then a slight post-Cretaceous uplift; then a Miocene sub- and more deposition; another elevation and the formation eat Kittatinny and other valleys, and the emergence of the by differential erosion; another submergence — the Pensau-en a broad sound extended from New York Bay southwest to peake, and the coastal plain was only half above the sea, as a sandy islands; then a slight uplift and further erosion, dur- time the glacial epoch brought its mantle of ice to the mid-e state, slightly masking the detail of the topography by d deposition of drift; during which time also the southern e state was submerged; lastly, a postglacial elevation to pres-de.

long record is made out by the most careful study of the phy, by the intelligent mapping and correlation of a vast

mass of detail and the whole interpretation stands as a monumental work in the young science of physiography.

The complexity of structure, the varying altitudes, the differential erosion, and the glacial interference have given many beautiful examples of readjusted drainage, some cases of which, *e. g.*, the Raritan and the Passaic, deserve to become classic.

The chief changes in postglacial time have been in the way of some readjustments of drainage in the drift, the beach action along the coast, and the building of dunes.

The whole of Part II, pp. 55–172, will be found a very valuable help to the teacher of physiography, and for these pages alone should be in every teacher's library. No plainer general statement of river action can be found than is here given (pp. 70–79).

The book is generously provided with maps of fine quality, with diagrams and sections, and with exceptionally clear half-tone insets of characteristic landscapes, all of which add very materially to the value of the work.

In the Appendix is collected a large mass of data, tables of geographical positions, of benchmarks, areas of drainage basins, forest areas, and tide tables. An account of the nationality and distribution of the population, and a statement of work accomplished in the magnetic survey closes the volume.

J. P. GOODE.

Bulletin of the American Museum of Natural History. Vol. X. 1898. New York.

Article IV. *A Complete Skeleton of Teleoceras fossiger. Notes upon the Growth and Sexual Characters of this Species.* By HENRY FAIRFIELD OSBORN.

Article VI. *A Complete Skeleton of Coryphodon radians. Notes upon the Locomotion of this Animal.* By HENRY FAIRFIELD OSBORN.

Article VII. *The Extinct Camelidae of North America and Some Associated Forms.* By J. L. WORTMAN, M.D.

Article IX. *Remounted Skeleton of Phenacodus primaevus. Comparison with Euprotogonia.* By HENRY FAIRFIELD OSBORN.

le XI. *Evolution of the Amblypoda,* Part I. *Taligrada and Pantodonta.* By HENRY FAIRFIELD OSBORN.

le XII. *Additional Characters of the Great Herbivorous Dinosaur Camarasaurus.* By HENRY FAIRFIELD OSBORN.

udents of vertebrate paleontology will find interesting mate- n this bulletin. Professor H. F. Osborn contributes five articles Dr. J. L. Wortman contributes one. Professor Osborn describes *ceras fossiger,* a complete skeleton of which has been mounted e American Museum, and calls attention to some of its salient cters. A complete skeleton of *Coryphodon radians* is also described igured. A study of this skeleton has revealed a number of new hological features which have an important bearing on the resto- ı and classification of the animal.

he interesting *Phenacodus primævus* of Cope's collection has been ved from its original matrix and mounted. The bones are thus d in their natural position and rendered available for detailed '.

The Evolution of the Amblypoda" is a somewhat extended e and is not complete in this bulletin. The author discusses the n of the Amblypoda and gives a synopsis of their evolution her with descriptions, relations and classification. The results of art I are well expressed in the author's own words, "First, the onstration of a number of phyletic lines of Coryphodons. Second, certain Coryphodons approach the Dinocerata in some structures osely as they depart widely from them in others."

'he reptile, *Camarasaurus,* is described from new material which s characters hitherto unknown. The author points out its relations *rontosaurus,* with which it compares in size, and writes of its habits peculiarities.

r. Wortman writes in detail of the Camelidae of North America. eviews the known genera and species and adds the descriptions of al new ones. The descriptions of many of the old forms are ified from new material. He makes a careful study of the Came- and gives their evolution as near as the incomplete knowledge of orms will follow.

W. T. LEE.

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IERICAN HOMOTAXIAL EQUIVALENTS OF THE ORIGINAL PERMIAN[1]

IN this country the Permian question has long remained open. various phases are essentially the same today as they were ty years ago, when Permian faunas were first thought to be ntified in the rocks of Kansas. For nearly a quarter of a ntury comparatively little information was added. Recently, wever, active interest in the subject has been renewed, and w data have been acquired. With this revival of interest bob also all the old questions. Concerning these there is as much fference of opinion as ever. Besides, new problems are pre- nted.

In all of the discussions concerning the American Permian hich have taken place in past years certain important facies of e theme have appeared to be wholly overlooked. In the ewer considerations there is also a manifest tendency to pass ver these very essential qualities. It seems pertinent, there- re, to consider briefly some of these phases of the subject. he following notes and comments are to be regarded as sug- estive along the line indicated. No formal attempt is made to orrelate in detail the terranes mentioned.

[1] Read before the Geological Society of America, December 28, 1898.

AMERICAN ROCKS ORIGINALLY REFERRED TO THE PERMIAN

Historical note.—Regarding the Permian in this country, three questions are prominently presented: (1) Should the Permian be recognized in America? (2) If so, what is the taxonomic rank of the succession of beds referred to it? (3) What are the upper and lower limits of the terrane so called? These questions are perfectly distinct, though they are usually considered together.

The introduction of Murchison's term Permian into the literature of American geology was due to Meek and Swallow, in 1858. The year previous, Hawn had collected, in central Kansas, the fossils identified by them as Permian forms. The beds from which these organic remains were taken form a part of an extensive sequence that extends in a broad belt from eastern Nebraska, through Kansas and Oklahoma, into central Texas. To this province the present notes refer.

After the first announcement of the discovery of supposed Permian fossils in this region, the subject was frequently discussed during a period of more than a dozen years. Meek, Swallow, Hawn, Shumard, Hayden, Newberry, Marcou, and Geinitz, made the principal contributions. Later White and Broadhead took up the subject to some extent. Recently Cragin and Prosser, in Kansas, and Cummins, in Texas, added much to our knowledge of the rocks in question.

The wholly disconnected character of the work of these authors is unfortunate. Except in a general way, is has been, heretofore, impossible to make any satisfactory comparisons between the different parts of the province. Only recently has any relationship been established between the results obtained by the various explorers of this region. Prosser has been chiefly instrumental in giving us something tangible to work upon. In connection with his own investigations, he has made a special effort to bring some of the earlier acquired results into close correspondence. The upper part of so-called Permian in Kansas still remains rather uncertain as to its natural subdivisions, and its relations to other sections. The lower part and the underlying

"Upper Coal Measures" along the Missouri River, which may be regarded as the standard section, have been lately carefully correlated.

The recent work has been sufficient to give us a good idea of the general character of the deposits regarded as Permian, the stratigraphical succession in the different parts of the province, the range of many species of fossils, and an outline of the main subdivisions that it will be useful to recognize.

Character of deposits.—The beds of the Continental Interior basin that have been considered as Permian, or Permo-Carboniferous and Permian, consist of two heavy shales, separated by thick limestones. The total thickness in Kansas is probably about 2000 feet; in Texas perhaps double this figure.

The lower beds are almost wholly made up of argillaceous and sandy shales, yellow, brown, green, and blue in color, and brown shaly sandstones. Occasionally occur thin, rather impure limestone bands, that carry abundant fossils. Near the bottom of the formation are some workable coals, associated with which is a characteristic flora.

The median number is composed largely of gray and buff limestones, often in thick layers, shaly limestones, and calcareous shales. The heavy limestones contain more or less chert in nodules and discontinuous bands. Abundant fossils are represented.

The upper part consists principally of gray, variegated, and red shales, and shaly limestones. Gypsum and salt deposits occur abundantly. Fossils occur only very sparingly.

In the main, the deposits indicate shallow waters, in strong contrast to the thalassic conditions that prevailed previously in the same regions. The sediments were laid down largely in closed basins, which finally become altogether dry.

General geological section.—In Kansas the general succession, as made out by Prosser and Cragin, is about as follows:

SECTION OF UPPER CARBONIFEROUS TERRANES OF KAN

Terrane	Thickness	Character
Kiger shales.............	210	Shales and sandstones, red chiefl "Red Beds"), with some gypsum dolomitic layers.
Cave Creek gypsum.......	40	Gypsum, massive, with some red sha
Salt Fork shales..........	1000	Shales, and shaly sandstones, re "Red Beds"), with rock-salt and
Wellington shales.........	350	Shales (lower salt measures), variousl gray predominating below, and g
Marion shaly limestones....	150	Limestones chiefly, gray and bu bedded.
Chase limestones..	250	Limestones, heavily bedded, much c calcareous shales.
Neosho shales............	140	Shales, yellow, green, and brown, thin limestone bands.
Cottonwood limestone.....	10	Limestone, fusuline, buff.
Wabaunsee shales........	550	Shales, sandy, argillaceous, with a coal seams.

Relations of Texas section.—In northern and central Te beds called Permian are well developed. Cummins se the succession into three parts, which he terms the Wich Clear Fork, and the Double Mountain, each being re about 2000 feet thick. According to this author, the sec the Paleozoic above the lower Carboniferous is:

CARBONIFEROUS TERRANES OF NORTHERN TEXAS

Terrane	Thickness	Character
Double Mountain.........	2075	Shales, red, sandy, often saline, w earthy limestones, and much gypsu
Clear Fork...............	1975	Limestones, and calcareous reddisl some sandstone.
Wichita.............. ...	1800	Shales and sandstones, and some c crates.
Albany..................	Wanting.	Limestones.
Cisco....................	840	Shales, with coal beds.
Canyon.................	930	Limestones, with shales.
Strawn.............	950	Shales and shaly sandstones.
Millsap..................	1000	Shales, with coal beds, and shaly sa
Lower Carboniferous......		

Just what parallelism should be instituted between the and Kansas beds is not yet quite clear. The apparent enc

development of the beds in question in Texas as compared with those north of the Wichita range, and the meager information, of an exact kind, regarding the former, make any attempt at correlation little short of guesswork. However, White's fossils, collected in the upper Wichita and lower Clear Fork, indicate an horizon near the Plattsmouth beds of Nebraska. The Albany seems to be very nearly equivalent to the Missourian series below the horizon just mentioned. The Double Mountain beds are, in a broad way, manifestly approximately equivalent to Cragin's Cimarron series. This leaves a considerable part of the Clear Fork beds representing the Chase and Marion of Kansas. There are in Texas indications of an unconformity at the base of the Clear Fork. Should this prove true, as now seems probable, it amply accounts for a number of hitherto inexplicable phenomena connected with the Kansas rocks, above the main limestones of the Missourian.

Organic remains.—It is unfortunate that, with all the advantages that the various workers in the so-called Permian have had, the information regarding the faunas is so meager. Fossils are abundant, at least up to the middle of Prosser's Marion. Such as have been recorded present some interesting phases.

It cannot be gathered from the discussions concerning the fossils found in the Upper Paleozoic west of the Missouri River, in Kansas and Nebraska, just what should be considered the typical "Permian" fauna. The appearance of abundant lamellibranchs and the disappearance of brachiopods seem, as noted elsewhere, to be the most notable features to which attention has been called. Geinitz, considering the fossils found in the Nebraska beds, which he referred to the Dyas, had before him both types. These strata are now known to be partly immediately below the Wabaunsee and partly the very base of the latter. Geinitz did not misinterpret their position so badly as Meek and others would have us believe. His comparisons were made with European standards, and if such comparisons can have any value at all they indicate a degree of acumen on the part of the German paleontologist that few Americans credit him.

Meek's exhaustive criticism of Geinitz's work on the Nebraska faunas, and his other papers on the same subject, appear to be largely misinterpreted by later writers. So far as I am able to find out, Meek's efforts were not directed so much against the view of the Permian age of the Plattsmouth beds as they were to emphasize the fact that the faunas followed one another unin terruptedly from the "Upper Coal Measures" up to the "Re Beds." He was unable to see how a "new and distinct system' could be represented in such a perfectly continuous sequence.

The case of Meek and Swallow is different. It was, afte all, a mere quibbling about unimportant details. With all thei bitter controversies, their views were not very far removed fro each other. Their subdivisions were practically the same. Onl different names were employed. Swallow regarded the Pale zoic section above (approximately) the Cottonwood limeston as divided into Lower Permian and Upper Permian. Meel selecting dividing horizons slightly different, called the or Permo-Carboniferous and the other Permian. Both agreed i the upper member being Permian. Regarding the lower membe Swallow thought Permian fossils predominated; Meek considere species of the Upper Coal Measures more abundant. Neith seems to have presented any decisive proofs one way or the othe

Prosser's late classification of the central Kansas rocks clain to be based upon the faunas. The subdivisions are proper given special geographic names, but the division lines are ve nearly the same as those selected by the earlier writers. Tl faunal evidence, as Prosser has set it forth in detail, appears oppose, rather than to support, the conclusions he has drawn.

Range of fossils.—In all the faunal considerations that rela to the Upper Paleozoic of Kansas, the rapid disappearance the brachiopod fauna "characteristic of the Upper Coal Me ures," and its replacement by a "Permian" lamellibranch fau is pointed out as very significant. Such a comparison is harc justifiable. The two cannot be thus contrasted any more thar fauna with a flora. They have no common points of relationsh The appearance of the latter in place of the former indicates

change in physical conditions, but in this case nothing more. Similar and even more marked changes occur at a hundred different horizons in the Carboniferous lower down. When shallow waters prevailed, lamellibranch and gasteropod faunas occupied the areas. When pelagic conditions occurred, the occupants of the district were chiefly brachiopods. The latter moved in as the former moved out. Comparisons of faunas of different classes avail little; they must be of the same class if tangible results are to be expected.

In drawing conclusions regarding the fossils of the beds that have been referred to the Permian and the Permo-Carboniferous, the utmost caution is imperative. The terranes have been only very imperfectly and very unequally explored. Comparisons of faunas have been largely between zoölogical groups of different classes. Many of the beds in the general vertical section are understood only in a vague way. There are long intervals about which nothing either stratigraphically or faunally is known. With a few isolated exceptions, organic remains have yet been found only in the lower half of the succession. Fossiliferous beds reach, according to our present knowledge, only up to the middle of the Marion. In Texas the "Permian" fossils described by White and Cope were from the Wichita and Lower Clear Fork beds.

Taking the fossils, the horizons of which are definitely known, and as chiefly determined by Prosser, fifty-two species are recorded from the Wabaunsee. Of these only two new ones occur in the Cottonwood. In the Neosho following, one third of the twenty-one species noted are not reported from the lower beds; they are lamellibranchs. In the Chase eleven of the thirty-three species appear for the first time. The Marion contains fewer species, but they are forms occurring at lower horizons. The principal brachiopods run through the whole sequence.

THE ORIGINAL PERMIAN

Historical statement.—The Upper Paleozoic rocks occurring along the western flanks of the Urals, in eastern Russia, in

Europe, were thought by Murchison to constitute a distinct system, equal in rank to Carboniferous and Silurian. He named it, in 1841, after the ancient kingdom of Perm. Since that time much has been learned regarding this great terrane in the Russian provinces. Numerous comparisons have also been made with supposed equivalents in other parts of the world.

A notable fact regarding the Russian Paleozoic rocks above the Devonian is that in nearly every respect they are very similar to those forming the same part of the general geological section developed in the Mississippi Valley. The original Permian presents almost the identical features that do the beds so called in Kansas and Texas. And, strangely enough, the identical questions that have arisen in this country are bones of contention among Russian geologists.

Those who took part in the long excursions in eastern, central, and southern Russia before and after the sessions of the Seventh International Congress of Geologists, held in St. Petersburg in August 1897, had ample opportunity to study the original Permian under the most favorable circumstances. Under the personal guidance of Messrs. Karpinsky, Tschernyschew, Pavlov, Amalilsky, and Nikitin, especially, the typical and critical sections were examined and the fossils of the various horizons collected. With the aid of the official maps, such literature of the region as was at hand, and the explanations offered by the geologists mentioned, who with others had worked in the district and were well acquainted with the details, an unusually good idea of the Russian Permian was obtained.

To those from America, who were especially interested in the Carboniferous and Permian, this experience furnished much desired information. The similarity of the deposits, of their faunas, and of the questions concerning them, in the Russia and Mississippi provinces, seems to make some comparison of their features worthy of formulation. The bearing that a direct knowledge of the former has upon the latter will certainly tend to make our own problems easier of solution.

Distributions of the terranes.—The Carboniferous and Permian

ɪcks of Russia extend from the Arctic Ocean to the Black ea—a distance of 1500 miles—and from the Urals westward a istance of 1200 miles. In the central and southern parts of ıe area is a thin covering of Cretaceous and Tertiary deposits. 'his vast basin, with its nearly horizontal strata, is comparable ɔ our own Carboniferous basin of the Mississippi valley. In he latter region the lower portion of the sequence — or Coal Ieasures — predominates. In Russia the upper part, or Permian, orms the surface in most of the region.

Around the margins of the great basin, especially on the vest and east sides, the Carboniferous is well developed. The ower Carboniferous, made up of limestones, is well displayed, ying immediately upon the Devonian. Relatively speaking, he Coal Measures are not very well represented, though the outhern coal field, or Donetz basin, covers 1200 to 1500 square niles, and the central field, or Toula basin, has about the same rea. On the flanks of the Urals some coal is also found.

The most typical sections of the Permian are in the Kama River Valley. The great Volga Valley, above Samara, is occupied hiefly by the so-called Permo Trias.

Nature of the rocks.—The beds that are called Permo-Carboniferous, Permian, and Permo-Trias, which occur in the Kama River 'alley present the most typical phases of Murchison's "system." 'he whole succession is tripartite. Shales, sandstones, and narls are separated medially by heavy dolomitic limestones.

The lower member consists of argillaceous and sandy shales, haly sandstones, marls, and some impure limestones. Someimes conglomerates are present. Abundant fossils are repreented. Upwards of 300 species have been listed. A distinctive lora is also present.

The median terrane is made up chiefly of massive dolomitic imestones, separated by calcareous shales. It forms a striking contrast to the beds above and below.

The upper member is formed of variegated argillaceous and sandy shales, brown shaly sandstones, some of which are copperbearing, marls, and occasionally thin limestone bands. Gypsum

is also frequently disseminated. The inferior portion is fossiliferous. Above this part come other shales, marls, and sandstones, almost destitute of fossils. They are thought by some authors to be Triassic.

The passage from the prominent marine phase of the Uralian Carboniferous to the subsequent shallow-water conditions is remarkable. The same closed basin depositions are as noteworthy as in the case of the American.

General section.—The Paleozoic beds above the strictly marine Carboniferous, as made out in the Ural region, are grouped by the Russian geologists in the following way:

UPPERMOST PALEOZOIC TERRANES OF EASTERN RUSSIA

Terrane	Symbol	Character
Tartaran	PT or P_s	Shales and marls, "Red Beds," very few fossils.
Zechstein (in part)	P_s	Marls, limestones, and sandstones.
———	P_b	Sandstones, shales, and marls with nodular limestones).
———	CP_c	Dolomitic limestones (base of Murchison's Permian).
Artinsk	CP_g	Shales, shaly sandstones. This and next terrane above are called Permo-Carboniferous.
———	C_s	Limestones.

Faunas represented.—The so-called true Carboniferous of the Urals is made up almost entirely of limestones. The highest member symbolized by the Russian geologists, C_3, contains a prolific fauna, which, while chiefly brachiopodous, has also a good representation of corals, some lamellibranchs, and fusulinæ.

Following, are the transition faunas to the Permian, according to the Russians, and by them called Permo-Carboniferous. The two members which comprise it contain, as pointed out by Tschernyschew, very nearly the same organic forms, consisting largely of lamellibranchs, gasteropods, and brachiopods. The lower terrane, termed the Artinsk, is notable for the ammonites that are found in it, which the author just mentioned compares with those lately found in the Texas Permian. The upper

ıne (CP_c), made up of dolomitic limestones largely, is the l number of Murchison's original Permian.

[The bottom terranes of the Permian, as now recognized he members of the Russian geological survey, present a t paucity of fossils. The forms are chiefly lamellibranchs, in some layers are fragmentary plants.

[The median part of the Permian carries what has been rded as the typical German Zechstein fauna.

About the upper terrane there is much dispute as to age. Russian geologists are about equally divided. Amalitzky iders it Permian. By others it is regarded as Triassic. sils occur rarely. Those found are chiefly lamellibranchs.

***Base of Murchison's Permian.*—As already noted incidentally, lower limit of the original Permian, as established by Murchi- in 1841, is the bottom of the dolomitic limestone immediately :lying what is called the Artinsk terrane. The geologists have worked in the region place this line in the middle of Permo-Carboniferous.** The succession of strata and the ıence of faunas are continuous from the Carboniferous to Permian. The transition is so gradual that it appears ossible to locate a satisfactory line of division between the . The conditions are identical with those that we have ountered in this country, and, following our example, the ısians have adopted our term — Permo-Carboniferous.

While the adoption of such a course emphasizes the transi- ıary character of the faunal sequence, it complicates, rather n simplifies, matters. Two important divisional phases are ɔgnized, both of which are as vague and unnatural as the one t this plan aims to obviate. On all other than faunal grounds, rchison's lower limiting horizon of the Permian is the most isfactory and perhaps also the most natural.

ɪPARISON OF THE RUSSIA AND MISSISSIPPI VALLEY CARBONIFEROUS

Stratigraphic parallelism.— In Russia and in the Mississippi ley the general geological sections of the upper Paleozoic

are remarkably alike. The basins occupied by these rocks
nearly of the same size. As already stated in the first-me
area, the Permian very greatly predominates as the surfa
In the last-named, the coal measures. The Carbonife
Russia presents two very distinct aspects—a thalassic
occurring on the western flanks of the Urals, and mad
limestones chiefly; and a shallow water or littoral phase
coal bearing, and that is best developed in the south
western parts of the great area, principally in the Don
Toula basins.

COMPARISON OF GENERAL SECTIONS

Russia	Character of Terranes	Mississippi V
Tartaran, Permo-Trias, or Upper Permian, P_3	Shales and marls, red and variegated, shaly sandstones; fossils rare; "Red Beds"	Cimarron Series
Middle Permian, P_2	Limestones, some dolomitic, separated by calcareous marl	(Marion li.) } Se
Lower Permian. P_1-b	Shales (only 200 feet thick in Kama Valley)	——— ?
Upper Permo-Carboniferous (base of original Permian) CPc.	Limestone, heavy dolomitic	(Chase li.)
Artinsk, CP.	Shales, sandstones, some thin limestones	(Neosho) (Cottonwood) (Wabaunsee) }
Upper Carboniferous, C_3	Limestones and shales, highly fossiliferous	Missourian Serie
Moscouan, Middle Carboniferous, C_2	Shales, sandstones, thin lime stones, coal-bearing	Des Moines Ser
Lower Carboniferous, C_1	Limestones chiefly, some shale and sandstone	Mississippian S

In the consideration of a theme like the present one, it is recognized at the outset, that comparisons of terranes of different geological provinces involves no necessary exact synchrony, except through absolute physical means of correlation. Such a standard, independent of intrinsic features of the terranes themselves, is not yet formulated for widely separated districts. The shortcomings of the common fossil criteria, in any other than the most general way and in the absence of something better, are well known. Any agreement of biotic features in stratigraphic successions distantly removed from one another are looked upon, so far as indicating simultaneous origin, only as happy accidents. Instead of furnishing proofs of time equivalency, it suggests for similar faunas only likeness of conditions, irrespective of time. Such faunal facies are only representative. They are merely homotaxial.

Any similarity of lithological succession is likewise accidental. The same is manifestly true of any other agreement of intrinsic features.

Nevertheless, a comparison of general geological sections in provinces so widely separated as the two under consideration, and so wholly distinct from each other in their origin, can be made not only suggestive but very profitable. The same problems for solution arise in both districts. The naturally different manner of treatment is mutually helpful in the solution of the various difficulties that are presented. Misconceptions regarding each are dispelled. Greater independence in the consideration of succession is established.

The most remarkable fact connected with the Russian section of the Upper Paleozoic and that of Kansas is that the two should be capable of any comparison at all. While the two differ much in stratigraphic, lithological, and biotic details, in general all three classes of characters present a very similar sequence.

Lithological features.—In the Russian and American Permian provinces, the field appearance of the rocks is very strikingly alike. This is particularly true of the upper half of the two sections. The general features are lost in the local examinations.

In the Russian district one finds it difficult to imagine that he is not wandering through some part of Kansas. Only the presence of the Russian peasant, or sudden contact with a village of the steppes dispels the illusion. In the Upper Paleozoic the aspects of the limestones and shales, their succession and expression are the same on the banks of the Volga or Kama as they are in the bluffs of the Missouri or Kansas rivers.

The original Permian strata are indistinguishable, lithologically, from the so-called Permian of Kansas. In both there are the same gray and variegated sandy shales and marls, passing locally into sandstones, that are often copper-bearing. Occasionally there are present thin bands and beds of buff earthy limestone. Gypsum is abundantly developed in beds and interspersed everywhere through the rocks. Saline shales are of not infrequent occurrence. On both continents all these pass upward into "Red Beds," that are almost destitute of fossils. Whether the last mentioned strata are Permian or Triassic is still, in both countries, an open question.

Range of faunas.—The succession of faunas appears to be essentially the same in the Russian Carboniferous and Permian as in the Mississippi valley. The composition of each of the faunas is also strikingly comparable. The most noteworthy feature of the organic remains, viewed as a whole, is the gradual replacement of a purely marine type by a shore and brackish water phase, as the change from open sea to closed water conditions took place, and finally to those in which life could not exist.

The most prominent characteristic of the biotic change from a Carboniferous phase to a Permian one seems to be the replacement of a predominantly brachiopod fauna by one in which lamellibranchs formed the preponderant element. This change has not, however, the deep significance usually attached to it. There are many other factors that appear to be largely or entirely overlooked. Faunal considerations should dwell more particularly on some of these other features, rather than upon a detailed tabulation of specific sequence.

The chronologic equivalence and comparison of rocks being universally based almost wholly upon the standard of the fossils is at best a very uncertain criterion. In the case of the Permian this uncertainty has been increased tenfold on account of the peculiar treatment that the fossils have received. The investigation of the biotic characteristics of the Upper Paleozoic has been very unsymmetrically developed and very unequally carried out. This is true in both Russia and America. From the published material no comparison of faunas is really possible; that is, in the sense that modern work demands. This chaotic condition of affairs is not anomalous. It occurs with many other faunas from many different horizons. In the present instance it is merely accentuated by a combination of accidental circumstances.

A most noteworthy factor is the extreme local character of the well known, published information. A single American instance suffices for illustration. Our best knowledge of the faunas of the Upper Coal Measures (Missourian) is derived almost entirely from a single horizon, at the single locality of Plattsmouth, Nebraska. This place has been made classic by Geinitz and Meek. All faunal comparisons, made through secondary means, of the rocks of the Mississippi valley above the lower productive Coal Measures (Des Moines) can take into consideration only the little pamphlet of Geinitz and the thin volume of Meek. Much has been made of this horizon by Waagen, Tschernyschew and other foreign paleontologists. Our American workers among the fossils have also depended largely upon the same sources of information.

As a matter of fact, the fauna of the Plattsmouth is characteristic not of a single, insignificant terrane, but of the entire Missourian series, and upward almost to the limits of the fossiliferous zones of the upper Paleozoic of the region — that is to the Marion. To be sure, as to numbers, the various species are differently represented at the several horizons; some forms are not reported yet from this level or that one; others appear that are not recorded from the Plattsmouth beds; yet, for a region in which no effort has ever been made to exploit systematically

the various horizons, and for a great succession of abundantly fossiliferous beds in which our published information is meager in the extreme, it is remarkable through how great a vertical interval the main characteristics of this Plattsmouth fauna are preserved.

The Plattsmouth remains are referred to as forming a characteristic maritime fauna. So it is, but it is identically the same fauna that is found at half a hundred other horizons between the lower coal measures and the "Red Beds." Whenever the heavy limestones occur the same groups of brachiopods appear. Whenever the more argillaceous shales are found the same lamellibranchs begin to predominate. Where the sandstone and coal-bearing shales are prominently developed coal plants and peculiar lamellibranchs and gasteropods are in evidence. These distinct faunas succeed one another in the same vertical section. They are repeated scores of times. Pretty nearly the same phenomena appear to obtain in the great Carboniferous basin of eastern Russia. In both regions the gradual replacement of the brachiopodous fauna by a "Permian" lamellibranch fauna follows the local change of open to closed sea conditions.

The Permian element of these faunas was merely a shallow water facies of the more typical Carboniferous fauna. It oscillated horizontally back and forth with each local change of bathymetric conditions. It was repeatedly intercalated between horizons carrying the greater thalassic phase. Meek's contention for the fauna of the Plattsmouth beds was for its identity with the fauna of the upper coal measures of the region. He was right. In his argument for the Permian character of the same fossils Geinitz was not wholly wrong. The point of vantage of each was merely slightly different. Could they have consulted more fully, they would have been no doubt soon in close agreement.

TAXONOMIC RANK OF THE PERMIAN

Principles of geological classification.—It is a well-known fact that the modern classifications of animals and plants are based primarily upon genetic relationship. A natural arrangement of

ck terranes is likewise genetic. It is strictly a function of ıuse and effect. It is only regarding the position of any parcular component in a classification, that is subject to a differıce of individual judgment. The taxonomic rank of a group ıay be subject to change as knowledge increases. Among rganisms an advancement in rank is frequent. Families eventally attain the rank of orders; genera of families; smaller roups are classed as genera. The same is true of geological ormations.

Recognizing, in the taxonomy of rock terranes, the five axonomic ranks of group or assemblage, system, series, stage, nd zone, as amply sufficient subdivisions, at least for all pracical purposes, a succession of beds at first given only the rank f a stage may be subsequently advantageously raised to that f series. Stage is a local unit; while series is a provincial one; nd system essentially universal.

In applying these principles to the Permian, the question esolves itself into two distinct phases: What should be conidered the taxonomic rank of the original Permian? and What s the rank of the succession of beds in this country, referred to he Permian?

Taxonomic position of the Original Permian. — Regarding the ank of the so-called Permian in general, there is much differnce of opinion. The older school of geologists, that is perneated thoroughly with the idea that fossil faunas are exactly ecognizable the world around, and that we can by them and vithout effort synchronize the provincial rock successions of lifferent continents, is inclined to recognize in the Permian a ıniversal extension, and to assign it a rank of a system, comparable to Carboniferous or Devonian. The more modern school of geological investigators, that tests classification and correlation by more that a single standard and that is seeking exact results and genetic relationships, would consider the original Permian as a provincial succession, and give it the rank of a series, under the more comprehensive system of the Carboniferous.

If one were to attempt anew to classify the upper Paleozoic deposits of eastern Russia, following the criteria that we have adopted in this country, he would have no hesitancy in assigning to the Permian of that region the rank of a series, and make it a subdivision of the Carboniferous. There is, however, a strong possibility of three or more well marked members being recognized in the original Permian succession, the rank of each of which is certainly higher than that of stage. The uppermost, or Tartarian, division is an example. This may prove to be Triassic in age. The inevitable tendency to advance the rank of such divisions, with the progress of knowledge regarding them, makes it almost certain that the divisions mentioned as having the same rank as the Tartarian, will be eventually regarded as series. Permian will then have to be either advanced to the rank of system, or to a new order intermediate between system and series. The latter course is manifestly not only unnecessary, but undesirable, and according to our present principles inadmissible. The former course is of very doubtful utility and not feasible on account of the almost universal apathy on part of geologists to increase the present number of recognized systems. When the time comes to regard the present divisions of the original Permian as distinct series, Murchison's term will be in all probability quietly dropped. It would appear then that all things considered the original Permian can be at best only regarded as a series and a part of the Carboniferous. The term [illegible] will then have an historical significance.

[illegible] *Permian rocks of the Mississippi valley.*—Most geologists who are at all familiar with the subject are inclined to regard the beds referred to the Permian as forming a minor division of the Carboniferous. The text-books [illegible] subdivide the Carboniferous [illegible] Lower Carboniferous [illegible] and the Permian. With the recent general [illegible] stratigraphic nomenclature [illegible] exactness by the [illegible] the first named division in this region has

called the Mississippian series. In its broadest sense the
lled Lower, or Productive Coal Measures finds satisfactory
ssion in the Des Moines series. For the "Upper Coal
ures" nearly to the usually selected horizon for the base
e Permo-Carboniferous, Missourian has been suggested as a
name.

he uppermost division of the Paleozoic of the region, the
widely designated as the "Red Beds," has received the
of Cimarron series. It appears to form a tolerably compact
nce, though there is still some dispute as to its exact
gical age. Between the Cimarron series and the Missourian
are two other terranes that are well defined. One is com-
l of the Chase and Marion of Prosser, in part, and the
of the Wabaunsee, Cottonwood, and Neosho.

ould some such subdivision of the Upper Paleozoic be
l applicable over the larger portion of the Mississippi basin,
w seems likely, the use of Permian and Permo-Carboniferous
e rapidly discontinued, or will be invoked only in historical
nce.

RELATIONS OF "UPPER PERMIAN" TO TRIASSIC

here is little satisfactory data upon which to correlate the
called Triassic in eastern United States with other regions.
leterminations appear to have been largely made upon litho-
l grounds and plant remains. There is no real physical
n between the Triassic, or Newark in the main, of the
tic border, and the Triassic of the region lying to the east
e Rocky Mountains.

he "Red Beds" of Kansas and Texas are thought by some
s to be Triassic in age; by others Permian. In the almost
absence of fossils in these beds, the lithological characters
eneral red coloration have been resorted to as criteria. Of
he question has been taken up anew. Prosser has been led
lieve that the greater part of the Kansas "Red Beds" are
ic. Williston, from even more reliable data, is inclined to
l the lower part at least as Paleozoic.

The question bids fair to remain unsettled, until some data more tangible and critical are obtained. The deposits of the Triassic of this region were laid down nearly under the same conditions as some of the so-called Permian. The beds appear to have been formed without interruption of sedimentation in enclosed basins. Vertebrate and plant remains are to be expected to form the prevailing forms of life. They cannot be very well compared with marine invertebrate faunas. Such a comparison would, if attempted, prove unprofitable. The clue must be evidently sought in physical criteria, and in the stratigraphy of the region. Sufficient work in this direction has not been done. The exact line of demarcation between the two must therefore remain undetermined for the present.

While this question is brought up at this time with the full knowledge that it has little bearing upon the main theme here presented, it is alluded to for the express reason that the same problem that has come up in connection with the deposits with which we have been comparing the American so-called Permian, has troubled the Russian geologists in their study of the original Permian area. Their Tartaran "Red Beds" are as perplexing as ours; and the opinions as to age are equally divided. Several writers, notably Karpinsky, Nikitin, and Tschernyschew are of the opinion that these deposits were laid down in isolated inclosed brackish water lakes, that continued to exist into the Triassic period. On the other hand, another group of equally shrewd observers, headed by Amalitzky, Schtukenberg, Netchaiev, and Krotov, regard all of these beds as Paleozoic. For all practical purposes the views of the last mentioned workers appear most reasonable.

In this country, the conditions appear identical with the Russian. Amalitzky's idea is equally applicable here, unless it is shown that marked and widespread unconformaties exist near or at the top of the American "Red Beds" and that the undoubted Triassic can be thus clearly separated.

RECAPITULATION

Returning to the original questions, propounded at the beginng, all available evidence appears to indicate :

1. That while we have in America a great succession of :posits identical in all essential respects to the original Perian of Russia, the two great basins merely had similar hisries that are not necessarily connected, and doubtless were holly independent of each other and unrelated ; that the Rusan Permian constitutes a geological province by itself ; and ıat therefore the term Permian should not be used as a technially exact term in connection with the Mississippi valley eposits.

2. That Permian, as originally proposed, applies to a proincial series, and according to our usual standard has at best a axonomic rank below that of system. Also, in view of the ›ossible elevation of its main subdivisions to the rank of series, he term will have no position in the general scheme of classiication. It will be no doubt eventually dropped altogether. The various series belonging to the succession and now having lower rank, will be considered main subdivisions of the Carboniferous system. In this country the same plan has been already proposed.

3. That, with the solution given to the second question, it is unnecessary to attempt to locate the limits of the so-called Permian in this country. The divisional lines of the series comprised in the typical American section in Kansas are already well defined, with the possible exception of that of the uppermost member.

CHARLES R. KEYES.

CORRELATION OF THE CARBONIFEROUS RO[illegible] OF NEBRASKA WITH THOSE OF KANSAS

IN THE JOURNAL OF GEOLOGY the writer published in [illegible] an article on the "Comparison of the Carboniferous and Per[illegible] Formations of Nebraska and Kansas"[1] in which he correl[illegible] the formations found in Nemaha, Otoe, and Cass countie[illegible] southeastern Nebraska with those of eastern central Kansas. [illegible] that time comparatively little work in areal geology had [illegible] done in northeastern Kansas, the Cottonwood limestone b[illegible] the only formation that had been even approximately traced f[illegible] the Kansas River north to Nebraska.[2]

The correlation of the formations in the above paper [illegible] based entirely upon their lithologic, stratigraphic, and fa[illegible] characters, for the writer did not have an opportunity to t[illegible] the distribution of any of the formations to the north of [illegible] Kansas River or to study the geology of the region bet[illegible] that river and Nemaha county, Neb. The rocks to the w[illegible] the Missouri River, covering the eastern part of Nemaha [illegible] and Cass counties, were correlated with the Wabaunsee[3]

[1] *Op. cit.*, Vol. V, No. 1, p. 16, and No. 2, p. 148.

[2] See "A reconnoissance geologic map of Kansas," in the Univ[illegible] Kans., Vol. I, 1896, Pl. XXXI.

[3] Since this article was written a paper has been published b[illegible] Keyes, in which he substitutes the name "Atchison [illegible] Shales" for th[illegible] mation (Am. Geologist, Vol. XXIII, pp. 304, 309, 31[illegible]) The clai[illegible] Atchison shales rests upon the fact that, in 1873, Pro[illegible] G. C. [illegible] under the general title of "Upper Coal Measures," [illegible] the follo[illegible] tion of the Upper Carboniferous rocks: "Gene[illegible] Measure rocks [illegible] the Atchison county group [illegible] Rep. [illegible] 1873, Part II, Ge[illegible] [illegible]

[illegible]

[illegible] was
[illegible] tional
[illegible] to trace
[illegible] of the
[illegible] between
[illegible] west of
[illegible] Ohio.
[illegible] forma-

[illegible]

[illegible]

already stated, Mr. Beede has traced the Burlingame ne from near Topeka to the Nebraska line, where it is, ntly, exposed in the bluff on the northern side of the Great ıa River, nearly due north of Robinson, Kansas. At the t the bluff, several feet below the limestone, coal has been which Mr. Beede thinks probably represents the Silver coal, and his description of the stratigraphic position of coal beds in northeastern Kansas strongly supports this ation.[1]

n the Kansas River the Wabaunsee formation has a thick-of 500 feet, and this, apparently, agrees quite well with the ness of the rocks included between the Burlingame lime- in southeastern Nebraska and the limestone west of Auburn, aha county, which is considered to cap the formation and rrelated with the Cottonwood limestone. Mr. Beede states it is but a short distance east of the exposure of Burlingame stone and coal in the bluff of the Great Nemaha to the 's mouth, where Hayden saw the outcrop of coal and sand- on the bank of the Missouri River.[2] This coal, according . Beede, "is without doubt the same coal that is mined on rth side of the Great Nemaha and, consequently, probably same horizon as the Silver Lake coal."[3]

s is an important correlation, for Meek was inclined to con-e outcrop at the mouth of the Great Nemaha as strati-ılly above the famous Nebraska City section, stating am inclined to believe this sandstone under the coal bed seen at Peru and Brownville, and at the base of on at Aspinwall, though it may be another holding a ition. If it is the same, there can be little doubt but ures here near Rulo hold a position in the series above n of the Nebraska City section."[4] Mr. Beede has

niv. Quar., Vol. VII, p. 232, and the forthcoming Vol. XVI, Trans. Kans.

p. U. S. Geol. Surv. Nebraska and portions of Adjacent Territories, nd 116.

ns. Acad. Science, Vol. XVI.

U. S. Geol. Surv. Nebraska, etc., p. 116.

also studied the Nebraska City section and, although he has not traced the strata from the mouth of the Great Nemaha to that locality, still he says: "the rocks at Minersville [formerly Otoe City] and Nebraska City are just what we should expect if Meek's correlations were correct, as a comparison will show: At the base of the Nebraska City section are several layers of limestone, then, above, a thick bed of shales and sandstones, coal and limestone, then over 100 feet of shales which contain a second coal, and above this another limestone, which makes it agree in stratigraphic succession, as it does in fossils, with the Topeka section. Thus, considering the great care with which Meek did the work, we can but come to the conclusion that his correlation is probably correct.

"If the foregoing statements are correct, we are forced to the conclusion that the Nebraska City section of Meek, from the base of the lower limestone to the top of the Minersville section, corresponds to the Topeka section from the Topeka limestone nearly to the base of the Burlingame limestone."[1] While in another article, in discussing Meek's reference of the sandstone at the mouth of the Great Nemaha to a stratigraphic position above that of the Nebraska City section, he says: "If this be true, it throws the section at Nebraska City in the same general horizon with the Topeka-Osage coal, if it be not identical with it, and the limestone at the base of the section would then represent the Topeka limestone, or a part of it. While I have not been over the ground between Minersville and Rulo, Neb., I am of the opinion that this conclusion is correct."[2]

The writer is inclined to consider the conclusion of Mr. Beede regarding the age of the Nebraska City beds as correct; and if so the rocks composing this section are equivalent to the Topeka limestone and Osage shalesof the Kansas River section, which form the upper part of Professor Haworth's Shawnee formation of the Upper Coal Measures.[3] This correlation agrees

[1] Trans. Kans. Acad. Science, Vol. XVI.

[2] Kans. Univ. Quar., Vol. VII, Ser. A, pp. 232, 233.

[3] Univ. Geol. Surv. Kans. Vol. III. p. 94.

ite closely with my earlier one, for it was stated in that paper at: "The writer is not confident whether the Nebraska City ds should be referred to the upper part of the Missouri formaon,[1] or to the Wabaunsee formation of the Missourian series. owever, the faunal and lithologic characters of the beds ar Nebraska City agree quite closely with those of the lower ılf of the Wabaunsee formation as shown along the Kansas iver above Topeka, and so the writer refers them provisionally it."[2]

The distribution of the carboniferous rocks in southeastern ebraska has been given by Mr. N. H. Darton, on a "Prelimiary Geologic Map of Nebraska,"[3] where they are represented nder the legend of the "Cottonwood and Wabaunsee formaons." On the same map, a part, at least, of the rocks mapped the Big Blue valley as "Permian limestone" may be correlted with the Chase formation of Kansas.

It will be remembered that Marcou referred the Nebraska ity beds to the Permian, and in this correlation he was suported by Geinitz, who described the fossils collected by Marou, and strongly opposed by Meek, who referred the rocks to e Upper Coal Measures. This difference of opinion led to a harp controversy, the essential features of which were noted my former paper.[4] There is now no question but that Meek as correct in referring these rocks to the Coal Measures, as as noted in the writer's former paper, and is now stated by Mr. eede.

It seems important, however, to again call attention to the act that Meek in correlating these rocks along the Missouri River in southeastern Nebraska with the Upper Coal Measures

[1] At the time the above article was written I understood that Dr. Keyes intended o retain the above name for that division of the Missourian series next older than the Wabaunsee formation. It was not used, however, and now Professor Haworth's Shawee formation includes that part of the series.

[2] JOUR. GEOL., Vol. V, p. 151.

[3] Nineteenth Ann. Rep. U. S. Geol. Surv., Pt. IV, Pl. LXXXII.

[4] *Op. cit.*, pp. 12-16.

did not intend to include the rocks in Kansas which he and Hayden had called Permian, a fact which has been overlooked by some of the later writers in considering the rocks of this region as the Permian. This was stated clearly enough by Meek when he gave his views regarding the age of these rocks as follows: "They . . . really belong entirely to the true Coal Measures, unless the division [illegible] the upper fossiliferous bed at Nebraska City, and some apparently higher beds below there on the Missouri, may possibly belong to the horizon of an intermediate series between the Permian and Carboniferous, for which in Kansas Dr. Hayden and the writer proposed the name Permo-Carboniferous. [illegible] It is true that in first announcing the existence of Permian rocks in Kansas, we also, upon the evidence of a few fossils from near Otoe and Nebraska Cities, resembling Permian forms, referred these beds to the Permian; but on afterwards finding that these fossils are there directly associated with a great preponderance of unquestionable Carboniferous species, and that there is also in Kansas a considerable thickness of rocks between the Permian and upper Coal Measures containing, along with comparatively few Permian types, numerous unmistakable Carboniferous forms, we abandoned the idea of including these Otoe and Nebraska City beds in the Permian. And all subsequent investigations have but tended to convince us of the accuracy of the latter conclusion."[1] This view was explained more fully in Meek's Review of [illegible] on the rocks and fossils of Nebraska, published in the November following his exploration there, in which, after describing a series of rocks occurring in Kansas, containing an extensive Coal Measure fauna, often mingled in the same beds with a few Permian types, he said: "In ascending several hundred feet higher in the series we observed the Coal Measure forms gradually dropping off until at last, above a certain undefined horizon, with the exception of one or two of the latter,

[1] [illegible] 1859, p. [illegible]; Proc. Acad. Sci. Phil., Vol. XI, 1859, pp. [illegible]; Am. Jour. Sci., 2d ser., Vol. XLIV, 1867, p. 37.

[2] [illegible] Rep. [illegible] Nebraska, pp. 130, 131.

only Permian forms were observed. Although we regarded these upper beds as the true representatives of the Permian, we gave a section of the whole series, down so as to include a considerable thickness of beds below, with lists of fossils, showing the range of the various types, without drawing any line of demarkation, because wè were satisfied nature had nowhere defined any abrupt physical or paleontological break here in the series,"[1] . . . . that is, that there is in this region [Kansas], a gradual shading off from an upper Coal Measure to a Permian fauna, through a considerable thickness of strata, forming a somewhat intermediate group, which we called the Permo-Carboniferous series ; also that there is no defined break between this intermediate series and the Permian above, or the Coal Measures below."[2]

It is also true that Hayden did not abandon the correlation of the highest Paleozoic rocks of Kansas with the Permian, for in July, 1867, he published some "Notes on the Geology of Kansas," in which he reviewed "Swallow's Preliminary Report of the Geological Survey of Kansas," not accepting his division of the Lower Permian as of true Permian age, and said: "As we ascend in the series, we find that, after going some distance above the supposed line of demarcation [Swallow's between the Lower Permian and Coal Measures] the Carboniferous species gradually begin to disappear, and the Permian types become rather more common, in particular beds, until we have ascended to a point near the horizon Professor Swallow makes the line between the Upper and Lower Permian, when we find we have almost completely lost sight of the familiar Carboniferous species, a few of which had continued on up to near this point, and see scarcely any but forms such as in Europe would be regarded as Permian types. There is no physical break here, however, nor *abrupt* change of fossils. Hence Meek and Hayden regarded the beds below the horizon down so far as to include most, if not nearly all, of Professor Swallow's Lower

[1] Am. Jour. Sci. 2d ser. Vol. XLIV, 1867, p. 334.

[2] *Ibid.* pp. 338–339.

Permian, as an intermediate connecting series between the Permian and Coal Measures which, if worthy of a distinct name at all from the latter, should be called Permo-Carboniferous, while the beds above they regarded alone as properly the equivalent of the true Permian of Europe.

The occurrence of a few types that would generally be regarded as Permian, along with numerous well-known Coal Measure species, far below the true Permian, only accords with facts observed in other formations in this country, where certain types evidently made their appearance here long before they are known to have appeared in Europe."[1] In discussing the rocks of Gage county, Nebraska, in the Final Report of 1872, Hayden also described a section on a small branch of the Big Blue River, near Beatrice, about which he wrote as follows: "Beds 1, 2, and 3 of the above section are undoubtedly of Permian or Permo-Carboniferous age, though they contain fossils common to both Permian and Carboniferous rocks. . . . . Bed 4 seems to form a sort of transition bed between the Permian[2] and Carboniferous [misprint for Cretaceous] formations."[3]

This later study of the rocks of southeastern Nebraska has made it possible for us to determine approximately how far below the base of Meek and Hayden's Kansas Permian the Nebraska City rocks occur, and this is perhaps its most important result. The line between the Permian and Permo-Carboniferous of Meek and Hayden was drawn at the top of No. 11 of their "General section of the rocks of [the] Kansas Valley;"[4] which, as I have shown, occurs about ninety feet below the top of the Chase formation.[5] Then, if we accept the correlation that

[1] *Ibid.*, p. 37. In this paper Hayden referred to notes which Meek had given him, stating that they "form the substance of this article." p. 321.

[2] It is not certain that the true Permian beds, as recognized in Kansas, extend northward into Nebraska, though thin beds may occur in some of the southern counties.

[3] Final Rep. U. S. Geol. Surv. Nebraska, etc., p. [illegible]

[4] Proc. Acad. Nat. Sci. Phila., Vol. XI, [illegible] and [illegible]

[5] Jour. Geol., Vol. III, pp. [illegible]

the top of the Minersville-Nebraska City section is stratigraphically a little lower than the Burlingame limestone, we will find that on the Kansas River, between the base of this limestone and that of Meek and Hayden's Permian are the Wabaunsee, Cottonwood, and Neosho formations, together with the greater part of the Chase formation, having a total thickness of approximately 900 feet. When it is also considered that massive limestones constitute a considerable portion of these rocks it will be seen that there is a decided time interval between the Nebraska City rocks and those of Meek and Hayden's Permian in Kansas. Or, again, the thickness of the rocks between the base of the Burlingame limestone and the base of Swallow's Lower Permian along the Kansas River, or Meek and Hayden's Permo-Carboniferous, is approximately 525 feet.

The failure to note the difference in age and faunas between the rocks of the Nebraska City region, along the Missouri River, and those of the upper Kansas and lower Smoky Hill River valleys in Kansas has led to certain erroneous statements and conclusions. This is possibly the explanation for the statement of Professor Calvin in his contribution to "A symposium on the classification and nomenclature of geologic time-divisions," in which he says: "The greater part of the assemblage of strata called Permian by Prosser and the geologists of Kansas University contains precisely the same fauna as our Missourian or Upper Coal Measures, and if there is no better excuse for recognizing Permian in America than that afforded by the beds in question, then America has no Permian."[1] The rocks which I have correlated as Permian, but without expressing a positive opinion as to whether the division should rank as a distinct system or as the upper group of the Carboniferous system (using Dana's stratigraphic terms) are the Neosho, Chase, Marion, and Wellington formations and the Cimarron group or Red-beds. The line between the Permian and the Upper Coal Measures or Missourian group was drawn provisionally at the base of the Neosho formation;[2] because in the Neosho and

[1] JOUR. GEOL., Vol. VI, p. 353.

[2] *Ibid.*, Vol. III, pp. 795, 800.

Chase formations zones occur in which there are numerous specimens of a few species which belong to genera that in Europe are regarded as of Permian age; but inter-stratified with these zones are others which contain numerous specimens of a considerable number of the Missourian species. The writer has already stated that "The Neosho and Chase formations are transitional from the Upper Coal Measures to the Permian as first defined by Murchison for Russia and belong to the division which has generally been called Permo-Carboniferous in this country. In accordance with the views of the majority of present European geologists familiar with this problem it is probably better to include the Permo-Carboniferous rocks of Kansas in the Permian series." The base of the Neosho formation is about [illegible] feet higher than the base of Swallow's Lower Permian or Meek and Hayden's Permo-Carboniferous, and the top of the Chase formation is approximately [illegible] feet higher than the base of Meek and Hayden's Permian, or between [illegible] and [illegible] feet above the top of Swallow's Lower Permian. The thickness of the Neosho is [illegible] feet and that of the Chase [illegible] feet, making a total thickness of [illegible] feet. Mr. Beede, who is describing the Carboniferous and Permian invertebrate faunas for the University Geological Survey of Kansas, writes me that "there is [illegible] between the Coal Measures and Permian [illegible]."

Succeeding the Chase is the Marion formation, with a thickness of from [illegible] to [illegible] feet. The lower portion of the Marion contains a fairly abundant marine fauna which, however, decreases [illegible] few species are found. The [illegible] has been found in this formation [illegible] which has yet [illegible] generally [illegible] Stratigraphy [illegible]

[illegible]

Myalina perattenuata M. & H., *M. permiana* (Swallow) M. & *Nautilus eccentricus* M. & H., *Nuculana bellistriata* Stevens var. *nuata* Meek, *Pleurophorus Calhouni* M. & H., *P. subcostatus* M. V., *P. subcuneatus* M. & H., *Pseudomonotis Hawni* (M. & H.) *P. Hawni* (M. & H.) sp. var. *ovata* M. & H., *Schizodus curtus* & W., *S. ovatus* M. & H., and *Yoldia subscitula* M. & H.

All of the species are Lamellibranchs with the exception of *Nautilus* which is a Cephalopod. One species begins in the ver Coal Measures; another is first reported from the Des ines of Iowa and then from the Kansas Permian, not appear- in the interval; six appear in the Upper Coal Measures and remaining six are known only in rocks of the age of Meek l Hayden's Kansas Permian, with one exception, which is orted from the Permo-Carboniferous of Utah and from rocks New Mexico referred doubtfully to the Upper Coal Measures.

The abundant species and about the only ones found in the per part of the formation are:

1. *Bakevellia parva* M. & H. — Permian of Kansas (in each instance aning that division of Meek and Hayden), and from Arizona in rocks ted by Dr. White to probably belong in the Permian, while he found a sely related form in New Mexico "at the summit of the Carboniferous ies" (U. S. Geog. Surv. W. 100 Merid., Vol. IV, p. 153). This species is sely related to *B. antiqua* Münster, which is common in the Permian of gland, Germany, and Russia.

2. *Myalina permiana* (Swallow) M. & H. — Permian of Kansas and xas. Reported by Hall & Whitfield from the Permo-Carboniferous of ah; and by Dr. White from New Mexico in rocks which were referred ubtfully to the Upper Coal Measures.

3. *Pleurophorus subcuneatus* M. & H. — Permian of Kansas; Dr. Keyes ports: "There is but little doubt that the form from Des Moines [Lower al Measure of Iowa] is identical with that figured by Geinitz in 1866 as *leurophorus simplus* of Keyserling" (Proc. Acad. Nat. Sci., Phil., 1891, p. 50) There is no other record, however, of the occurrence of this species ntil Meek and Hayden's Permian is reached in Kansas, and Mr. Beede nforms me that he has not seen it below the Permian there. This species is nearly related to the *P. simplus* v. Keys. sp. of the Russian Permian that einitz regarded them as identical.

4. *Pseudomonotis Hawni* (M. & H.) sp. — Permian of Kansas. Heilprin

reported from the Upper Coal Measures of Pennsylvania "an obscure impression which may be that of this species, but very doubtful" (Second Geol. Surv. Pa., Ann. Rep., 1885, p. 455). Mr. Beede writes me, however, that it begins near the base of the Upper Coal Measures of Kansas, and he will shortly publish an article describing the Kansas species of this genus. This species was regarded by Swallow and Geinitz as identical with *P. speluncaria* Schloth. sp., which is a common Permian form in England and Germany.

5. *Myalina perattenuata* M. & H. also occurs near the top of the Marion and is reported from the Permian of Kansas and Texas, and the Upper Coal Measures of Missouri and Illinois.

The only Brachiopods found are specimens of *Derbya* from the lower part of the formation, which are doubtfully referred to the species *D. multistriata* M. & H. sp., which occurs in their Kansas Permo-Carboniferous. The disappearance of the Brachiopods was perhaps due in part to the diminished depth of the water, but in a much greater degree, undoubtedly, to the highly concentrated nature of the waters, as shown by the deposits of rock salt and gypsum. This change in the condition of the water affected the other forms of life unfavorably; but there remained, as we have seen, a meager Lamellibranch fauna which differed decidedly from the Lamellibranch fauna of the Coal Measures and is closely allied with the Permian Lamellibranch fauna of Europe.

The Wellington formation succeeds the Marion, varying in thickness from about 200 feet on the Smoky Hill River to 450 feet in Sumner county, near the southern line of the state,[1] in which, as far as known to the writer, no fossils have yet been found.

The Paleozoic of Kansas closes with the Cimarron group or the Red-beds, which in the southern part of the state are from 1150 to 1400 feet thick.[2] The absence of fossils has formerly made the correlation of this group rather indefinite. Professor Cragin has compared the stratigraphy of the Red-beds of the Kansas-Oklahoma basin with those of northern Texas and stated

[1] Univ. Geol. Surv. Kans., Vol. II, p. 67.

[2] *Ibid.*, p. 88.

ıt the gypsum beds of the Cave Creek formation, the top of ich is about 250 feet below the summit of the Kansas Red-ds, apparently connect them "by a bond of stratigraphic con-ıuity with the demonstrated Permian of Texas."[1]

Fossils have recently been found about 100 feet above the se of the Cimarron group in the northern part of Oklahoma. ıe most abundant specimens are species of a Phyllopod Crus-cean which unfortunately were poorly preserved and, there-ıre, identified with some doubt by Professor T. Rupert Jones s *Estheria minuta* Alberti sp.[2] This species is characteristic of ıe Triassic in England, France, and Germany, apparently ccurring most abundantly in the Keuper of the Upper Triassic.

Associated with the Crustacean fossils was the greater part ıf the skeleton of an Amphibian which has been identified by ʼrofessor Williston "as *Eryops megacephalus* Cope, a form lescribed from the 'Permian' of Texas." Professor Williston, n discussing the importance of this discovery in reference to the ıge of the Red-beds, says: "This identification settles once for ıll the horizon whence it came as Permian, if the Texas beds be really of that age. There are several hundred feet of deposits n Kansas above this horizon that still possibly may be consid-ered as Triassic, but there is no reason for so doing. *Estheria minuta* is a Triassic species, but, even if correctly determined, ts value is slight in comparison with that of the vertebrate in he correlation of the beds. It must be remembered, however, hat *Eryops* is by no means necessarily characteristic of the Per-nian."[3]

Professor Williston has written me as follows regarding Cope's correlation of the Texas deposits with the Permian: "In his first work upon the Texas beds Cope determined them as Triassic, and he seems never wholly to have overcome the idea

[1] Colorado College Studies, Vol. VI, p. 5; see also pp. 2, 3, 30, 48. The correla-on of the Red-beds from this stratigraphic evidence was discussed by the writer in e Univ. Geol. Surv. Kans., Vol. II, pp. 89–92.

[2] Geol. Mag., Dec. IV, 1898, Vol. V, p. 292.

[3] Science, N. S., Vol. IX, Feb. 10, 1899, p. 221.

that they may not be of Triassic age, but in all his later papers upon the forms he refers to the beds as Permian. I suppose the reason for this collocation is the fact that the nearest related forms are found in the European Permian. Thus, *Euchirosaurus* and *Actinodon* are referred to the lower Permian in France (the Rothliegenden of Autun). I at first thought that the present form might be *Actinodon*, but the bones made out agree quite closely with the figures of *Eryops megacephalus* given by Cope."[1]

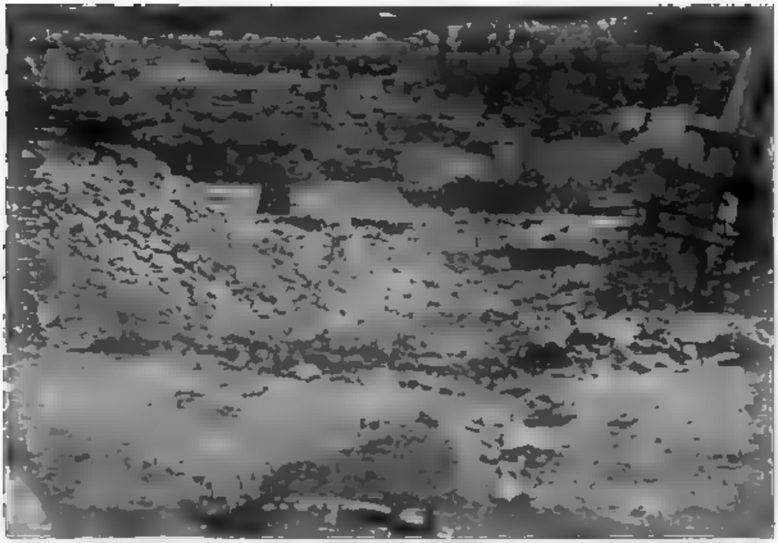
The above brief summary of the Permian rocks of Kansas shows that fossils occur in beds varying in thickness from 1000 to 1350 feet; while if all of the Red-beds are of the same general age, as is possible, the estimated total thickness of the Permian would then range from 2050 to 2650 feet. The majority of the species found in the lower 400 feet, the Permo-Carboniferous deposits, occur in the Upper Coal Measures (Missourian), and perhaps one half of the species in the succeeding 300 or 400 feet; but above that horizon none have been found which are even closely related to those in the Coal Measures. On the contrary, this higher fauna seems to be as nearly related to the Triassic as to the Carboniferous. This would seem to be sufficient proof that the greater part of Permian strata does not contain "precisely the same fauna as our Missourian or Upper Coal Measures," since only the lower 400 feet of deposits, ranging in thickness from 1350 to perhaps 2650 feet, contain a fauna composed largely of species which occur in the Upper Coal Measures. These lower beds are transitional, but this fact does not seem to the writer to furnish sufficient proof that the higher ones at least are not of Permian age.

CHARLES S. PROSSER.

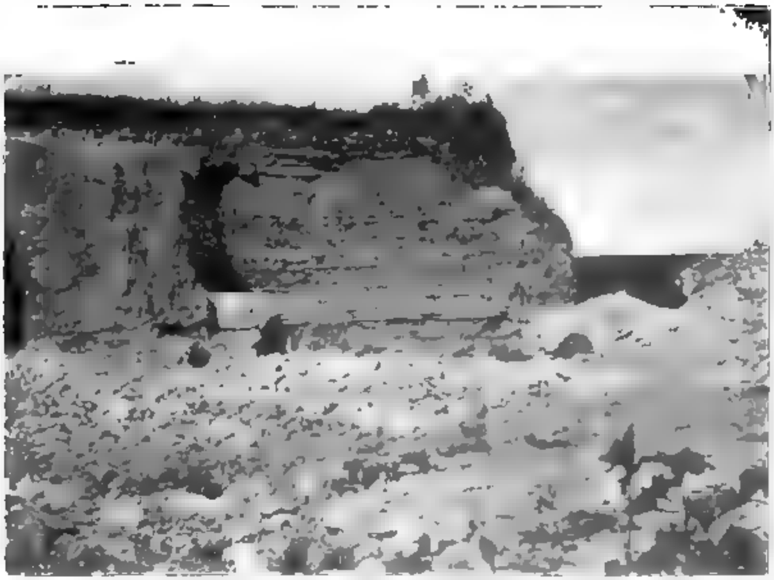
UNION COLLEGE,
March 1899.

[1] Letter of Feb. 26, 1899.

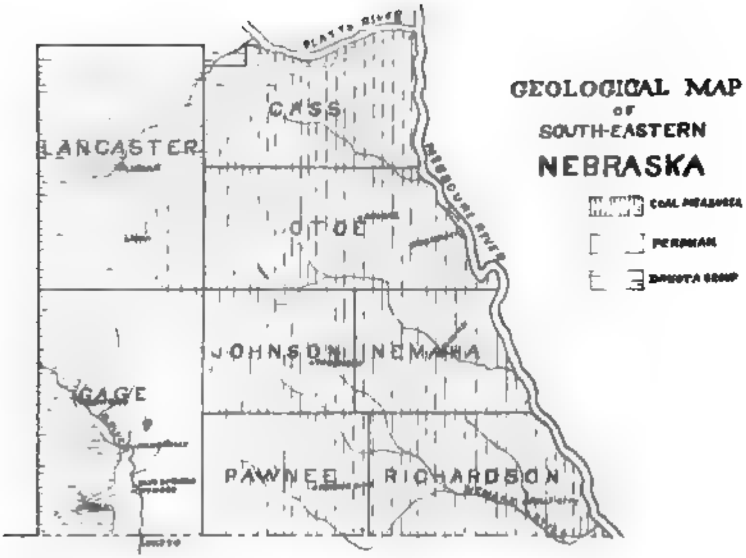
[To be inserted between pp. 356 and 357, May–June number, 1899.]

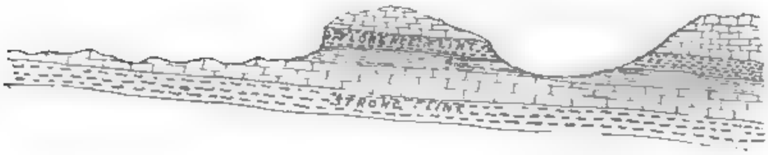


Limestone Quarry above Florence Flint. Blue Springs, Neb.



Exposure of Florence Flint in a Quarry East of Wymore, Neb.





A GEOLOGICAL SECTION OF THE NEBRASKA PERMIAN FROM BEATRICE SOUTH AND EAST TO THE KANSAS LINE.

THE NEBRASKA PERMIAN[1]

WHETHER or not true Permian rocks occur in Nebraska has been an open question for many years. Nevertheless, it has been customary for geologists mapping southeastern Nebraska to assign to it a narrow belt of territory extending from a point on the Nebraska-Kansas line sixty miles west of the Missouri River, north and east to Omaha. So far as the literature on the subject goes, there is absolutely no data that would warrant this construction. Probably these maps have been constructed upon the supposition that, since Permian rocks were known in Kansas, they might extend northward into Nebraska, and in case they did they would be found between the Carboniferous Coal Measures and the Dakota sandstone of the Cretaceous.

Professor Marcou[2] was the first geologist to suggest the occurrence of Permian rocks in Nebraska. Prior to that time the Paleozoic escarpments along the Missouri River had been considered Carboniferous by both Nicollet[3] and Owen.[4] In studying this region Professor Marcou made a very thorough examination, and it was his candid opinion that the rocks were

[1] In 1885, while a student in the University of Nebraska, the question of the occurrence of the Permian rocks in Nebraska came up in class and was thoroughly discussed, some maintaining the statements of Marcou, others those of Meek. The result was anything but satisfactory, and Dr. Hicks suggested to me that it would be a good plan to investigate the Paleozoic rocks of Nebraska and determine, if possible, whether there were any rocks that could be assigned to the Permian. This was carried out. The Missouri River, Platte River, Cass, Otoe, Richardson, Johnson, and Pawnee counties were visited, and Meek's conclusions that these rocks were Coal Measures confirmed. Still believing that the Permian rocks might occur in the southern portion of the state, work was resumed in Gage county. The data collected at that time are here presented in their original form, except that there are numerous references to Prosser's papers.

[2] Bull. Soc. Geol. France, 2 ser., Jan. 1864, Vol. XXI, pp. 134-137.

[3] NICOLLET's map.

[4] Report of the Geol. Surv. of Wis., Iowa, and Minn., and incidentally of a portion of Nebraska Territory, pp. 133-135.

Dyas (Permian). Later Professor Geinitz,[1] of Dresden, studied the fossils collected by Professor Marcou, and in an article confirmed Marcou's classification. The work of Marcou and Geinitz called forth some severe criticism from American geologists, which culminated in Professor Meek's masterly production in the Final Report of the U. S. Geological Survey of Nebraska, in which he proved conclusively that the Missouri River rocks extending from the mouth of the Platte River, southward along the Missouri River in Nebraska, were Coal Measures. The only recent publication bearing on the subject of the Missouri River rocks in Nebraska is an article published by Professor Prosser,[2] in which he strongly supports Meek's views. Without question these rocks must be considered Coal Measures.

Early investigators paid little or no attention to the Paleozoic exposures lying some distance west of the Missouri River. While making his reconnaissance for the final report on the geology of Nebraska, Dr. Hayden suggested that the true Permian rocks as found in Kansas might occur in some of the southern counties of Nebraska. However, his statements are very confusing and assure one that he had not arrived at any definite conclusion. While suggesting in a footnote[3] that the Kansas rocks might extend northward into Nebraska, on the same page, in discussing the Beatrice section, he says: "Beds 1, 2, and 3 of the above section are undoubtedly Permian or Permo-carboniferous, though they contain fossils common in both Permian and Carboniferous rocks. . . . . Bed 4 seems to form a sort of a transition bed between Permian and Carboniferous formations. The Permian rocks pass beneath water level at Beatrice westward," etc. The fossils on which the above statements in reference to the Beatrice section were made were *Syntrilasma* (*Enteletes*) *hemiplicata* and *Pinna peracuta*. Dr. Hayden visited many outcrops within the Permian area in Gage

[1] M. d. K. Leop. Carol. Acad. d. Naturl. Carbonformation und Dyas in Nebraska. Dresden, pp. vii + 91. 5 plates.

[2] Jour. Geol., Vol. V, No. 1, pp. 1–16, and No. 2, pp. 148–172.

[3] U. S. Geol. Surv. of Nebraska, final report, p. 28.

›unty while making his survey. In his report he mentions the ınds of cherty limestone so characteristic of the Kansas beds ıd many other features that could only lead one to correlate ıese formations. Unfortunately, it has been found impossible to lentify Dr. Hayden's sections along the Big Blue River. The ːasons for this are apparent when it is known that he speaks of ıe bluffs at Blue Springs as being from ten to fifteen feet high, 'hen in reality they vary from fifty to ninety above the river. ›ince Dr. Hayden's report nothing of importance was published ›ertaining to these rocks until 1886, when L. E. Hicks,[1] then ˀrofessor of Geology in the University of Nebraska, published :wo short papers. These articles were so general in character :hat it was impossible for any one to arrive at any definite conclusion regarding the area under discussion. In 1897 Prosser published two articles in which he discussed and reviewed the work of previous writers on the Paleozoic of Nebraska, and compared the Missouri River rocks with the Kansas beds. In the first of these articles[2] Prosser refers briefly to the exposures along the Big Blue River, and concludes by saying: "These rocks are undoubtedly of Permian age, and it is probable that the Neosho formation, and possibly a part of the Chase, occurs in Gage county."

Since the discovery of Permian rocks in Kansas by Swallow[3] there has been a considerable time devoted to their study by numerous geologists. The stratigraphical features are well known and the fauna has been carefully studied, although there is much to be accomplished in a more exhaustive study of the fossil life. Recently Prosser[4] has brought together all of the

[1] Transactions A. A. A. S., Buffalo meeting, 1886, and the American Naturalist, Oct. 1886. pp. 882, 883. The data embodied in these two articles were taken from my notes.

[2] Jour. Geol., Vol. V, p. 12.

[3] See Trans. Acad. Sci. St. Louis, Vol. I, pp. 111, 112.

[4] See Bull. Geol. Soc. Am., Vol. VI, pp. 29-54; Jour. Geol., Vol. III, 1895, pp. 682-705 and 764-800; University Geol. Surv. of Kansas, Vol. II, pp. 55-96. See also an article by Professor Haworth in the University Geol. Surv. of Kansas, Vol. I, pp. 185-194.

history bearing on these rocks, and added much valuable information to the literature by a careful examination of the many exposures. His classification must stand as a basis for correlating the Permian rocks of the central western United States.

The Nebraska Permian is the northern extension of Kansas beds, and agrees with them in all of the essential characters. The area is of a flatiron shape, with the broad end to the south resting upon the Kansas-Nebraska line. The northern limit is probably in the vicinity of Roca, Lancaster county. On the east the boundary has only been approximated, since the highlands separating the valley of the Nemaha from the valley of the Big Blue River, are so deeply buried with loess that there are few, if any, rock exposures. Typical Permian rocks were found near the eastern line of Gage county, and Coal Measures near Pawnee City, Pawnee county. From these data it is supposed that the eastern boundary of the Permian extends from Roca south and east into Johnson county, thence southward through the western end of Pawnee county into Kansas. The western boundary, from Roca to Beatrice, is also buried beneath a very thick bed of loess ; but from Beatrice southward it was traced with considerable accuracy, since there were numerous outcrops of both Permian and Dakota sandstone. Only a short distance west of Beatrice the Dakota sandstone crosses the river and trends south and east along the southwestern border of the valley of the Big Blue River to a point known as "The Mounds," which is a high bluff capped by Dakota sandstone on the west bank of the river some two miles west of Holmesville. From this bluff, the highest in this section of the country, the boundary trends south and west, passing several miles west of Blue Springs, thence westward along the north side of Indian Creek to a point about two miles west of Odell, where it crosses the creek and turns eastward and follows the south side of the valley of Indian Creek nearly to the Big Blue River, where it bends southward and keeps a southern course to the Kansas line. As bounded, this area, comprising nearly five hundred square miles, is nearly confined to Gage county, and, with the exception of that portion in

ncaster county, is drained by the Big Blue River and its butaries. This river enters the central western border of the rmian field and flows eastward and southward through the stern half into Kansas. All of its tributaries in the Permian cks are small streams and of little importance.

The topography of this region is wholly unlike that of any her part of the state. There are highlands of almost level airie, which change gradually into rolling prairie, and in some calities the rolling prairie shades into rough and broken couny that is only fitted for pasture land. As the tributaries pproach the river they usually flow through narrow, deep ravines r gulches, and in numerous places there are miniature canyons ith precipitous walls of cherty limestone. The Big Blue River lows through a gradually narrowing valley. At Beatrice the luffs are low and well rounded and the valley quite wide. In the vicinity of Holmesville, the bluffs are very much higher and steeper, and near the Kansas line they are from fifty to one hundred and fifty feet high and in many places very precipitous. Where the exposures approach the perpendicular the walls are usually cherty limestone. The chert, which is almost black, occurs in regular bands of varying thicknesses. These exposures, when viewed from a distance, with their alternating layers of light and dark stone, partly vine-clad, remind one of the work of man rather than nature; and it does not require a vivid imagination for one to see ruin after ruin as the eye wanders down the river; here an old fortress, there an old church, and in the distance the rude outline of an old crumbling castle. This rugged scenery, mingled with the many groves and the winding river, makes this one of the most picturesque localities of the state. The elevation of this region above the sea varies from 1150 feet, at the state line, to about 1300 feet, on the divide between Roca and Beatrice. Judging from the deposits of drift along the river, the Permian has undergone glaciation. There are a few V-shaped troughs, varying in depth from two to five feet, and these are usually filled with granite and quartzite pebbles and sand. The Big Blue River was very near the southwestern limit of the great

ice sheet. North and east of Holmesville there are a few isolated patches of Dakota sandstone that have escaped glaciation.

In studying the Permian, work was commenced at Roca, but on account of the slight exposure and the scarcity of fossils, no detailed examination was made. A few specimens of *Enteletes hemiplicata* (Hall) were all the fossils seen, and the vertical range of this species is too great to allow it as evidence for or against the Permian. In the vicinity of Beatrice, only two slight exposures of yellowish shelly limestone were found. One of these was just below the dam, on the east bank of the river, and the other on the west side of the river in a ravine about a half mile southwest of the upper bridge. These rocks[1] were barren of fossils. By following the Union Pacific railroad down the river about a mile below town, a slight exposure of very poor limestone was found in a cut. From this point southward the limestone surface along the bluffs gradually rises above the railroad grade which follows the course of the valley. Three miles below Beatrice at the old cement mill, the following section was taken:

No. 4. Soil and drift - - - - - - -	4 feet
No. 3. Yellowish shelly limestone - - - -	4 feet
No. 2. Cellular light gray limestone - - -	13 feet
No. 1. Bluish hydraulic limestone - - - -	8 feet
Total, - - - - - - - -	29 feet

No. 1 of this section was utilized during the seventies for manufacturing hydraulic cement. Nos. 1 and 2 contained the following fossils:

Productus semireticulatus Martin.
Ambocelia planoconvexa Shum.
Meekella striatioconstata Cox.
Seminula argentea Shep.
Bellerophon sp.

From the old cement mill down along the river on the east bank there are numerous exposures of the above section. At "The Mounds" the Permian is capped with about forty feet of brown Dakota sandstone, and the junction of the two formations

[1] Dr. Hayden reports two species. See final report of the U. S. Geol. Surv. of Nebraska, p. 28.

·ely obliterated with soil and débris. Numerous slight ıres of Permian rocks were found that were above the t mill section and with them *Seminula argentēa* (Shep.) but er fossil.

Holmesville there were numerous exposures and many of had been opened as quarries. To the north of the depot is a quarry face over a quarter of a mile in length and aver- twenty feet in height. The limestones of this quarry are ck bedded and one band has a peculiar habit of changing or from a bluish to a cream color within a distance of y feet. South of the bridge there is a thin bed of oölite hickens rapidly toward the south. It is very fossiliferous, hins out before reaching the quarries north of the depot, : the following section was made :

No. 5. Soil, sand and drift - - - - - -	9	feet
No. 4. Yellowish to bluish limestone with geodes filled with quartz crystals, in some places cellular and containing fossils - - - - - -	10½	feet
No. 3. Bluish limestone - - - - - -	4	feet
No. 2. Cherty limestone - - - - - - -	6	feet
No. 1. Unexposed to the river - - - - -	14	feet
Total - - - - - - - - -	43½	feet

: oölite has not been included in this section but belongs ı Nos. 3 and 4, which are quarried for building purposes. lowing fossils were taken from the oölite and No. 4.

Productus semireticulatus Martin.
Meekella striatiocostata Cox.
Aviculopecten occidentalis Shum.
Aviculopecten sp.
Aviculopecten sp.
Schizodus ovatus M. and H.
Schizodus wheeleri Swal.
Schizodus sp.
Yoldia subscitula M. and H.
Bakevellia parva M. and H.
Edmondia sp.
Edmondia sp.
Loxonema sp.

Pleurotomaria sp.
Murchisonia nebrascensis Gein.
Bellerophon montfortanus N. and P.
Naticopsis cf. *remex* White.

Southwest of Holmesville two and a half miles, on the west bank of the river, there is a long escarpment of very excellent limestone, that in early days was quarried and transported by wagons as far as Lincoln, to be used for building purposes. It occurs in good workable beds and breaks across the bedding as well as with it. When the stone is taken from the quarry it is easily cut with saw or plain, but upon exposure it becomes very much harder. When large dry blocks are struck with a hammer they have a metallic ring. It has been called magnesian limestone, and resembles very much the so-called magnesian limestones, that have been quarried from the Kansas Permian for many years.

SECTION OF QUARRY

No. 6. Cream colored limestone - - - -	$\frac{5}{6}$ foot
No. 5. " " " - - - - - -	2½ feet
No. 4. " " " - - - - -	3⅓ feet
No. 3. " " " - - - - -	3 feet
No. 2. " " " - - - - -	3 feet
No. 1. Bluish and gray limestone - - - - -	8 feet
Total - - - - - - - -	20⅔ feet

The position of this section in reference to Holmesville is questionable. Levels were not run but there is some evidence that it occupies a place lower than the Holmesville bed. Possibly it may represent the Holmesville section in part; the differences in the strata being accounted for by a difference in sedimentation. Only a few fossils were found.

Aviculopecten occidentalis Shum.
Sedgwickia alteristriata? M. and H.
Myalina aviculoides M. and H.
Derbya robusta Hall.
Edmondia sp.
Pleurophorus sp.
Slight impressions of *Nautilus* or *Metacoceras* and a large pelecypod.

next examination was made at Blue Springs. The bluffs e the town are from fifty to ninety feet above the river d extend down the stream for two or three miles. The riking feature of these bluffs is the thick bed of cherty ne that has not been seen to the northward, but which t be found at "The Mounds," or along some of the high- way from the river. Below the cherty band along the the slopes are in many places paved with large blocks of limestone that have been loosened by frost. Above the layer, there are several bands of workable limestone that een quarried for building purposes. While the Blue s exposure is above the Holmesville, it is not definitely what it rests upon. It is quite possible that there is a of rocks intervening that have not been discovered.

BLUE SPRINGS SECTION

No. 10.	Soil	2 feet
No. 9.	Yellow shelly limestone	5½ feet
No. 8.	Compact yellowish limestone containing vertebrates and many invertebrates	7½ feet
No. 7.	Cherty limestone, fossiliferous	1½ feet
No. 6.	Yellowish soft limestone	1⅔ feet
No. 5.	Cherty limestone, fossils in chert	16 feet
No. 4.	Indurated and variegated marls	20 feet
No. 3.	Bluish limestone	10 feet
No. 2.	Unexposed	10 feet
No. 1.	Bluish limestone	3 feet
	Total	69⅔ feet

s. 7 and 8 contain a great many fossils, some of which w to science. The following were collected:

Productus semireticulatus Shum.
Meekella striatiocostata Cox.
Orthis sp.
Seminula argentea Shep.
Aviculopecten occidentalis Shum.
Aviculopecten maccoyi M. and H.
Aviculopecten sp.
Orbiculoidea sp.

Orbiculoidea sp.
Bellerophon sp.
Myalina permiana? Swal.
Rhombopora lepidodendroides? Meek.
Myalina aviculoides M. and H.
Dentalium sp.
Derbya crassa M. and H.
Derbya robusta Hall.
Strapharollus subrugosus M. and H.
Archeocideris sp.
Fenestella sp.
Polypora sp.
Fistulipora sp.
? ? Ceromya sp. probably a new genus of pelecypods.
Vertebrates:
  Styptobasis knightiana Cope.
  Diplodus sp. nov.

Professor Cope[1] in describing Styptobasis as a new genus remarked: "This was a large shark of carnivorous habits, and its presence indicates the existence of a marine fauna whose remains have not been discovered." Associated with No. 8 was a huge Pinna nearly three feet long.

Quarries and exposures were also examined in the vicinity of Wymore, but no additional data were secured, since the sections were the same as at Blue Springs.

At Odell several slight exposures were found along the bluffs, and one in a small gulch west of the town. From the last one mentioned a single specimen of *Chænomya minnehaha* (Swal.) was taken. On account of the exposures being slight, and no chance to study more than a few feet of limestone, the Odell region was not worked over. From a few measurements of rock in place the dip was found to be slightly to the southwest.

The exposures along the river south from Wymore, are very numerous and in many places form continuous bluffs, but none of these were critically examined until the Kansas-Nebraska line was reached. Here there were the finest exposures seen along

[1] See COPE'S description, Proceedings of the U. S. Nat. Museum, Vol. XIV, pp. 447, 448.

river, and they were also quite accessible for study. The rty band as seen at Blue Springs can be seen on every bluff, the limestones above resemble the stone quarried at the Blue ings quarries. But above all of these bands, there are several t have not been seen to the north. The following section ; made at the state line.

No. 7.	Yellowish oölitic limestone - - -	8½ feet
No. 6.	Light colored limestone, shelly - - -	4 feet
No. 5.	Yellowish limestone - - - - -	8 feet
No. 4.	Light colored limestone with some chert -	13 feet
No. 3.	Very cherty limestone - - - - -	15 feet
No. 2.	Indurated marls, variegated - - -	15 feet
No. 1.	Unexposed to the river - - - - -	20 feet
	Total - - - - - - - -	73½ feet

No fossils were found below the cherty bands. Nos. 5, 6, d 7 contained a great many fossils, No. 7 being especially rich species as well as in numbers. The following is a partial list. ıny of the fossils were so frail that by the time they had been cked, shipped, and unpacked no one could identify them,

Nautilus eccentricus M. and H.
Metacoceras dubium Hyatt.
Metacoceras sp.
Myalina aviculoides M. and H.
Myalina perattenuata M. and H.
Myalina permiana Swal.
Myalina sp.
Seminula argentea Shep.
Pseudomonotis hawni M. and H.
Pseudomonotis hawni ovata M. and H.
Pseudomonotis sp.
Meekella striaticostata Cox.
Derbya crassa M. and H.
Derbya robusta Hall.
Aviculopecten occidentalis Schum.
Aviculopecten sp.
Bakevellia parva M. and H.
Pinna sp.
Yoldia subscitula M. and H.
Schizodus sp.

Schizodus sp.
Solenomya sp.
Solenomya sp.
Fenestella sp.
Pleurophorus sp.
Edmondia sp.
Scaldia sp. nov.
Allorisma subcuneata M. and H.
Allorisma cf. *elegans* King.
Chaenomya laevenworthensis M. and H.
Bellerophon marcouanus Gein.
Bellerophon sp.
Avicula cf. *lanceolata*.
Orthoceras sp.

At Oketo, Kan., two miles south of the state line, there are large quarries worked in the bands above the cherty limestone. The exposures along the bluffs at Oketo were the same as seen at the state line, except there were a few new bands above the oölitic limestone. The cherty limestone band that has been traced from Blue Springs to the state line and on to Oketo is, beyond question, the same band that outcrops to the north of Marysville, Kan., and that it is the Florence[1] flint of Prosser's Chase formation. If this correlation is correct, the cherty limestone that is only partly exposed at Holmesville will eqaal the Strong flint of Prosser's Kansas section, in which case the Chase formation would extend as far north as Beatrice, and the Neosho from Beatrice to Roca. There are some stratigraphical differences noted while comparing the formations of the two states, but this will undoubtedly disappear with more detailed study. The most marked is the occurrence of oölites in Nebraska that have not been reported from Kansas. Prosser calls the variegated band underlying the Florence flint a shale, while the same band in Nebraska is an indurated marl. At all exposures attempts were made to take the dip, but as a rule the readings were anything but satisfactory. At Holmesville and Blue Springs there were places, which appeared to be caused by warping, where

[1]See PROSSER's conclusion as to the Marshall county, Kansas rocks, Vol. V, JOUR. GEOL., p. 12.

strata dipped slightly to the east, but in the same quarries e could find slight dips in almost any direction.. By com- ring the height of the base of the Florence flint with the rail- d grade at Blue Springs and Oketo, it was found that these cks had a southern dip of five feet to the mile. This informa- n, coupled with the readings taken at Odell, makes it very cer- in that these rocks dip to the southwest.

In comparing the fossil life of the two states there are greater fferences than one might expect, especially when the Upper ermian rocks are not known to Nebraska. So far there are any more lingering Coal Measure species reported from Kansas an Nebraska. As soon as the questionable species of both tates have been classified, the greatest differences in the fauna ill disappear. There is another interesting point that is not out f place here. There are a few species of invertebrates reported rom the Texas Permian that are common to the Permian of Kan- as and Nebraska, and beyond question, when the Texas species f gasteropods and pelecypods have been reported in full, there vill be many more species common. It seems very probable hat the Permian of Kansas and Texas was at one time con- ected, and that it also stretched westward and northward to, nd possibly beyond, the Rocky Mountains. Many of the early eologists connected with the geological surveys of the territo- ies considered that the uppermost rocks of the Paleozoic in the nountain region was Permian, and so recorded it; but owing to he lack of paleontological evidence, but few, if any, have ever onsidered this classification correct. Only recently fossil hori- ons of great importance have been discovered in what will in he future be known as the mountain Permian. These fossils re in part the same as those found in the Permian of Kansas nd Nebraska, but with them are numerous forms new to science vhich are decidedly Mesozoic in character. When the mountain ormations have been thoroughly investigated, the Permian area f the United States will be materially increased.

Some may question whether there are any true Permian rocks[1]

[1] See PROSSER's discussion of this subject in Vol. III, JOUR. GEOL., pp. 789–796.

in America. A discussion of this subject cannot be taken up here, but the following notes are worthy of consideration. Of the forty-four genera of invertebrates known in the Kansas and Nebraska rocks, over three fourths of them belong to the Permian of the Orient. The remainder are nearly all American genera and are chiefly pelecypods. In referring to the English Permian it will be seen that there are reported thirty species of brachiopods and thirty-seven species of pelecypods, while in America, with a fauna only partially known, there are fifteen brachiopods and between forty and fifty species of pelecypods. Besides this, there is the disappearance of the Spirifers, the most of the Producti, and the most of the typical Coal Measure species.

Some have objected to the use of the term Permian to designate an American terrane. There seems to be no good reason for this. In this country, as in Europe and India, there is a series of rocks above the Coal Measures that cannot be consistently classified with them. While they are linked with the Paleozoic with unmistakable affinities, they are also bound to the Mesozoic by indubitable bonds. Since the term Permian has been in use many years to represent this formation, in this, as well as foreign countries, it seems ill advised at this time to introduce a new term to designate the American formations. We might as consistently cast off other period names that have had their origin in a foreign country. Since the Permian is a typical transition series, it seems advisable to speak of it as a geological period of the Paleozoic, and no longer consider it an epoch of the Carboniferous.

In order to show the close relationship of the American and foreign Permian, a table has been arranged which will give all of the genera known to the Kansas and Nebraska Permian, and also show their distribution in the foreign Permian. The resemblance is even greater than appears in the table, since it has been impossible to secure accurate data relating to many of the foreign genera.

...VING THE KANSAS AND NEBRASKA (AND IN PART THE ...) PERMIAN INVERTEBRATE GENERA AND THEIR DISTRI... IN THE FOREIGN PERMIAN

	England	Russia	Germany	India	Kansas	Nebraska	Texas
					+		
	+	+			+		
...laris	+	+			+	+	
					+		+
	+	+	+	+		+	
		+	+	+	+	+	
				+?	+		
...ra				+	+	+	
...s				+		+	
...lea	+	+	+		+	+	
	+	+	+	+	+	+	
	+	+	+	+	+		
		+	+	+		+	
	+		+	+	+	+	
			+	+	+		
...s					+	+	
	+	+	+	+	+	+	
...ten	+	+	+	+	+	+	+
	+			+		+?	
...nolis	+	+	+	+	+	+	
	+?	+	+?		+	+	
	+?			+	+		
		+			+	+	+
		+		+	+		
	+	+		+	+		
					+	+	+
	+	+	+	+	+	+	+
	+	+	+	+	+	+	
...rus	+	+	+	+	+	+	+
						+	
	+	+		+	+	+	
	+	+	+			+	
						+	
...a					+	+	+
...a					+	+	
	+	+	+	+	+	+	+
...na					+		
...s	+		+		+	+	
...m			+	+	+	+	+
	+	+	+		+		

A LIST OF THE KANSAS AND NEBRASKA PERMIAN FOSSILS[1]

	England	Russia	Germany	India	Kansas	Nebraska	Texas
Gasteropoda.							
Macrocheilus	+	..	+	+	+	..	..
Orthonema?	..	..	..	..	+	..	..
Aclisina	..	..	..	..	+	..	..
Strapharollus	+	..	+	+	+	+	+
Naticopsis	..	..	..	+	+	+	+
Pleurotomaria	+	+	+	+	+	+	..
Murchisonia	..	+	+	+	+	+	+
Cephalopoda.							
Orthoceras	..	..	..	+	..	+	+
Nautilus	+	..	+	+	+	+	+
Metacoceras	..	..	..	..	+	+	..
Phacoceras	..	..	..	..	+	..	..
Crustacea.							
Phillipsia	+?	..	..	..	+	..	..
Pisces.							
Styptobasis	..	..	..	..	..	+	..
Diplodus	..	..	..	..	..	+	..

	Nebraska	Kansas	Texas
Fistulipora sp	+	..	..
Chaetetes cf. *carbonaria* Worth	..	+	..
Zaphrentis sp	..	+	..
Archaeocideris sp	+	..	..
Archaeocideris sp	..	+	..
Spirorbis cf. *permianus* King	..	+	..
Spirorbis? orbiculostoma Swal	..	+	..
Spirorbis sp	..	+	..
Fenestella shumardi Prout	..	+	..
Fenestella sp	+	..	..
Polypora submarginata Meek	..	+	..
Polypora sp	+	..	..
Rhombopora lepidendroides Meek	+?	+	..
Rhombopora sp	+	..	..
Septopora biserialis Swal	..	+	..
Orbiculoidea sp	..	+	..
Orbiculoidea sp	+	..	..
Orbiculoidea sp	+	..	..
Productus semireticulatus Martin	+	+	..
Productus semireticulatus calhouni Swal	..	+	..
Productus nebrascensis Owen	..	+	..
Productus costatus Sowb	..	+	..
Chonetes granulifera Owen	..	+	..
Orthis sp	+	..	..
Derbya crassa M. & H	+	+	..
Derbya multistriata M. & H.	..	+	..
Derbya robusta Hall	+	..	..
Meekella striaticostata Cox	+	+	+
Meekella shumardiana Swal	..	+	..

[1] The fossils reported from Kansas are those that have recently been reported by Professor Prosser. The Texas list has been reported by Professor Cummings, and the Nebraska from my collections.

HE KANSAS AND NEBRASKA PERMIAN FOSSILS—*continued*

	Nebraska	Kansas	Texas
	+	..	..
lcata Hall	+	+	..
iaconvexa Shum	+	+	..
itia Shep	+	+	..
ccidentalis Shum	+	+	+
rboniferous Stevens	..	+	..
maccoyi M. & H.	+	+	..
p.	+	..	..
sceolata[1]	+	..	..
lawni M. & H.	+	+	..
awni ovata M. & H	+	+	..
cf. *variabilis* Swal.	..	+	..
p	+	..	..
Shum	+	+	..
	+	..	..
	+	..	..
	+	..	..
irostris M. & W	..	+	..
nuata M. & H.	+	+	+
ensis Shum	..	+	..
ana Swal	+	+	+
oides M. & H.	+	..	+
vi McChes.	..	+	..
	+	..	..
triata attenuata Meek	..	+	..
icki Schauroth	..	+	..
'a M. & H.	+	+	+
a M. & H.	+	+	.
s M. & H.	.	+	..
s M. & H.	+	+	..
eri Swal	+	..	..
rtiformis Walcott	..	+	..
	+	.	..
	+	.	..
bcostatus M. & W.	.	+	..
. *oblongus* Meek	..	+	..
bcuneatus M. & H.	..	+	
).	+	.	.
).	..	+	..
	+	.	.
muni M. & H.?[2]	..	+	.
nebrascensis Gein.	.	+	.
	+	..	..
	..	+	.
	+		..
	+	..	..
nov.	+	..	.
rostrata M. & H	+?	+	..
nehaha Swal	+	+	..
enworthensis M. & H	+	..	..

ossil Conchology, Brown, Plate LXIX, Fig. 3.

recently been referred to Pleurophorus. See Bull. U. S. Geol. Surv., UART WELLER, p. 242.

A LIST OF THE KANSAS AND NEBRASKA PERMIAN FOSSILS—*continued*

	Nebraska	Kansas	Texas
Allorisma subcuneatum M. & H	+	+	+
Allorisma cf. *elegans* King	+	..	..
? *Glauconome* sp.[1]	..	+	..
Dentalium meekanum Gein (?)	..	+	..
Dentalium sp.	+	..	..
Bellerophon montfortanus N. & P	+	+	+
Bellerophon, cf. *sublaevis* Hall	..	+	..
Bellerophon marcouanus Gein	+	..	..
Bellerophon sp	+	..	..
Bellerophon sp	..	+	..
Loxonema ? sp	+	+	..
Macrocheilus angulifera White[2]	..	—	..
Orthonema ? sp	..	+	..
Aclisina robusta Stevens	..	+	..
Aclisina swallovana Gein	..	+	..
Straparollus subrugosus M. & W	+	+	..
Straparollus subquadratus M. & W	..	+	+
Straparollus pernodosus M. & W	..	+	..
Naticopsis, cf. *remex* White	+	..	—
Pleurotomaria sp	+	..	..
Murchisonia, cf. *nebrascensis* Gein	+	..	..
Murchisonia sp. nov	+	..	..
Orthoceras sp	+	..	..
Nautilus eccentricus M. & H	+	+	..
Metacoceras dubium Hyatt	+	+	..
Metacoceras sp	+	..	..
Metacoceras sp	—	..	..
Phacoceras dumbli Hyatt	..	+	..
Phillipsia sangamonsis M. & W	..	+	..
Phillipsia sp.	..	+	..
Styptobasis knightiana Cope	+	..	..
Diplodus sp. nov	+	..	..

W. C. KNIGHT.

[1] Referred by STUART WELLER to Pinnatopora. See Bull. U. S. Geol. Surv., No. 153, p. 288.

[2] Conditionally referred to *Soleniscus angulifera*. See Bull. U. S. Geol. Surv., No. 153, p. 339.

THE DIAMOND FIELD OF THE GREAT LAKES

THE diamonds which have from time to time been discovered the region of the Great Lakes of North America, now num-:r seventeen, not including those of microscopic size. With the ıgmentation of the number of stones the problems arising out their distribution in the glacial drift, and particularly those lating to the source or sources from which they have been :rived, assume increasing interest.

HISTORICAL INTRODUCTION

The first mention of diamonds from this region in any scien-fic work appears in the *Mineral Resources of the United States for e year 1883–4*,[1] in which Kunz refers to the sensation caused y the reported diamond discovery near Waukesha, Wisconsin, 1883. The "booming" of the property for diamond mines ıd the alleged discovery subsequently of two diamonds which unz found to have the aspect of African stones, very naturally d this eminent authority to discredit the discovery at this ace of the larger stone as well, and to consider the entire fair as a so-called "plant" to influence speculation.

In the summers of 1887, 1888, and 1889, Mr. G. H. Nichols, Minneapolis, assisted by Messrs. W. W. Newell and C. A. awn, of Rock Elm, Wis., prospected for gold in the bed of lum Creek, Rock Elm township, Pierce county, Wisconsin. In ıe course of their work they found ten or more diamonds, vary-g in weight from ½ carat to 2 carats, besides a number of ones of microscopic dimensions.[2] The stones were found

[1] G. F. KUNZ: Mineral Resources of the United States, U. S. Geol. Surv. 1883–4 885), p. 732; see also Gems and Precious Stones of North America, New York, 90, p. 35.

[2] G. F. KUNZ: Diamonds in Wisconsin, Eng. and Min. Journ., Vol. L, 1890, p. 6; see also a paper by the same author in Bull. Geol. Soc. Am., Vol. II, 1891, 638.

in the well-worn gravel of the bed of the creek, associated with garnets, gold, and platinum. Some were colorless but others were bluish or slightly yellowish. Three of the stones, which were sent to Mr. Kunz for examination, weighed respectively $\frac{25}{32}$, $\frac{7}{16}$, and $\frac{3}{32}$ of a carat.

In November 1893, a white diamond of $3\frac{13}{16}$ carats, weight was brought to the writer in a collection of quartz pebbles, by Charles Devine, a farmer of Oregon, Dane county, Wisconsin. The stones had been found in October of the same year by a small son while playing in a clay bank on the farm of Judson Devine, in the town of Oregon, which is about twelve miles south of Madison.[1]

The writer's interest having been aroused in the occurrence of these stones, he began to investigate the Waukesha sensation and after some correspondence learned that a yellow diamond of over 15 carats weight was in the possession of Colonel S. B. Boynton, a jeweler of Chicago. From Mr. Boynton was learned the history of this stone, which was undoubtedly found as reported, at Eagle, near Waukesha, Wisconsin. The stone was brought to light in 1876 while digging a well on the farm then owned by Thomas Deveraux. The diamond was noted as something peculiar, and was given to Mrs. Clarissa Wood, who, with her husband, was a tenant on the property. Seven years later, in November 1883, while still ignorant of the real nature of the stone, she sold it to Mr. Boynton, at that time conducting a jewelry business in Milwaukee, for the sum of one dollar. Colonel Boynton submitted the stone to competent examination and learned that it was a diamond. Upon hearing of this Mrs. Wood offered to repurchase the stone for $1.10, and upon his refusal to accept this offer, brought suit against him to recover the full value of the stone. After extensive litigation the case was brought to the supreme court of the state, from which a decision was handed down in favor of the defendant, on the

[1] WM. H. HOBBS: On a recent Diamond Find in Wisconsin, and On the Probable Source of this and other Wisconsin Diamonds, Am. Geol., Vol. XIV, 1894, pp. 31-35; see also, Diamanten von Wisconsin, Neues Jahrb. f. Mineral., 1896, II, p. 249.

nd of his ignorance of the nature of the stone at the time ırchasing it.

'he writer called upon Colonel Boynton at Chicago, and was 'ed to examine the stone. Both it and the Oregon diamond subsequently purchased by Tiffany & Co., of New York, ıre still uncut in the Tiffany collection.[1]

'hrough Mr. Boynton the writer learned that a large dia-1 had been found in 1884 (this date should be 1886), by a er named Endlich, at Kohlsville, near West Bend, Washing-:ounty, Wisconsin. The stone had been brought to Mr. ıton's shop for examination, and he had remembered it as a -yellow diamond, weighing 21¼ carats. After considerable :spondence this diamond was located by the writer in the ession of Mrs. Louis Endlich, of Kewaskum, Wis, the w of the man who had discovered the stone in the neigh-ıg town of Kohlsville. On visiting Kewaskum the writer allowed to examine the stone, which proved to be in all :cts as described by Colonel Boynton, and there is no doubt the weight (21¼ carats) reported by him is approximately :ct, since this stone is considerably larger than the one from e. Mrs. Endlich stated that her diamond was found by her and in the spring of 1886 while plowing a field on his in the town of Kohlsville.[2] This stone is still in her pos-on.

n 1894 Mr. Kunz reported the finding by Mr. Frank B. kmond of a diamond weighing almost 11 carats, at Dowagiac, county, Michigan. This locality is to the southeast of Lake ıigan, on the Michigan Central railway, between Niles and mazoo. The stone was found in the glacial drift and some h was subsequently made in the vicinity for other stones, vith negative results.[3]

WM. H. HOBBS: *loc. cit.*, p. 32.

VM. H. HOBBS: N. J. B., 1896, II, p. 33; also Bull. Univ. Wis., Sci. Ser., Vol. . pp. 152–154; see also, G. F. KUNZ: Eighteenth Annual Report U. S. Geol. 't. IV, 1895, p. 596.

G. F. KUNZ: Sixteenth Annual Report U. S. Geol. Surv., 1895, Pt. IV, p. 596.

In March, 1896, a stone was brought to the office of the Wisconsin state chemist, at Milwaukee, which, on examination, proved to be a white diamond of nearly 6½ carats weight. It was found by Conrad Schaefer, a German farmer at Saukville, Ozaukee county, Wisconsin. In a letter to the writer, Mr. Schaefer says of this stone (translation):

This diamond is from a little collection of gems, stones, and fossils, also Indian implements, all collected on my land. My land adjoins the Milwaukee River, and is a drift range running northeast and southwest. I had the stone about fifteen or sixteen years in my possession.

This diamond was purchased by Messrs. Bunde & Upmeyer, the well-known Milwaukee jewelers.[1]

In 1893 Messrs. Bunde & Upmeyer purchased from Mrs. G. Pufahl a white diamond of about 2 carats weight, said to have been found at Burlington, Racine county, Wisconsin. Little was learned at the time of the circumstances attending the finding of this stone, and the writer's subsequent attempts to get into communication with Mrs. Pufahl, though kindly assisted by Messrs. Bunde & Upmeyer, have not been successful. Like most of the others, this diamond was probably found in the glacial drift.[2]

The latest diamond to come from the region under consideration was found so recently that nothing is in print concerning it, except in the newspapers. It is a diamond of purest water, weighing 6 carats, and was found in 1897 by two small daughters of J. R. Taylor, at the town of Milford, Clermont county, Ohio. It is now owned by Herman Keck, of Cincinnati, and has recently been cut into the form of a brilliant. Before cutting a cast was taken of it and the stone is now being studied by Professor Thomas N. Norton, of the University of Cincinnati.

It is seen from the foregoing that no less than seventeen well-identified diamonds, varying in weight from ½ carat to over 21 carats, have been discovered in the region of the Great Lakes of North America. That a considerable number of others have been found which have not been reported because they have

[1] G. F. KUNZ: Eighteenth Annual Report U. S. Geol. Surv., 1897, Pt. V, p. 1183.

[2] G. F. KUNZ: *Ibid.*

escaped identification, hardly admits of reasonable doubt, when it is borne in mind that three of the stones found (including the two of largest size) remained in the hands of the farming population without their nature being discovered, for periods of eight and one half, seven, and over fifteen years, respectively. If it were possible to visit all the homes in the lake region, I have no doubt that many diamonds would be discovered in the little collections of pebbles and local "curios" which accumulate on the clock shelves of country farmhouses.

Since 1894, when the writer published a note on the Eagle, Oregon, and Kohlsville diamonds, and ventured to predict that other diamonds would occasionally be found in the glacial drift, they have been coming to light in this region, at the rate of about one each year, though not apparently as the result of search in any case.

PHYSICAL CHARACTERISTICS OF THE LAKE DIAMONDS

It will be profitable to consider the physical peculiarities of the several diamonds which have been found in the lake region, and to compare them with one another in order to determine whether points of resemblance or of difference are the more remarkable. They may be considered in respect to size, form, surface, and color. The observations of specific gravity and of index of refraction, which would be of great interest, have not as yet been carried out upon them.

Size.—The size of the lake diamonds is best indicated by their weights, which range from $21\frac{1}{4}$ carats (Kohlsville) to the microscopic diamonds of Plum Creek. In descending order the weights of the stones which have been examined are respectively $21\frac{1}{4}$, $15\frac{12}{32}$, $10\frac{7}{8}$, $6\frac{13}{32}$, 6, $3\frac{14}{16}$, $2\frac{1}{16}$, 2, $\frac{25}{32}$, $\frac{7}{16}$, and $\frac{3}{32}$ carats. While the average weight of these is over 6 carats, it cannot be considered an average for the region, since only the larger stones are likely to be discovered until a systematic search is undertaken in the region. At Plum Creek, where panning of the gravels was undertaken, the diamonds found were mostly small, the largest being of 2 carats weight.

Crystal form.—The crystal form of the lake diamonds f
nishes the most important method of comparing them. T
prevailing forms are the rhombic dodecahedron, the rhom
dodecahedron with vicinal faces of a hexoctahedron, and a h
octahedron. The exceptions to the rule are found in the Sa
ville stone, a trisoctahedron; the Burlington stone, a tet
hedron; and the Milford stone, which from the newspa
accounts would seem to be an octahedron. Twinning v
observed in one of the Plum Creek diamonds (in a hexoc
hedron) and in the Burlington stone (in a tetrahedron).

The crystals possessing dodecahedral and hexoctahed
habits show, therefore, close affinities in their crystal forms, t
Eagle and Kohlsville stones, which are crystallographically alm
identical, being essentially intermediate between the Oreg
dodecahedron and the Plum Creek and Dowagiac hexoc
hedrons. On all the crystals the faces are rounded, and uneq
development has produced distortion. The Eagle diamo
approaches nearer to the ideal form than any of the others whi
I have examined.

Surface.—Surface markings are common to most of t
stones. These are generally pittings, irregular in some cas
but generally circular or triangular. On the Eagle stone th
are triangular elevations.

Color.—The color of the diamonds in this region varies fr
"white" to white tinged with green, and to pale yellow. T
stones of Milford and Saukville are "white." White stones w
faint grayish-green tinge (probably external) were found
Oregon and Burlington, and one from Plum Creek; while t
Eagle and Kohlsville stones and some of those from Plum Cre
are "Cape-white" (pale yellow). The several stones exhi
also varying degrees of transparency, the Milford stone part
ularly being of a remarkably pure water.

For purposes of comparison the most important facts rega
ing the larger diamonds have been brought together in the tal
on the opposite page.

ONE	Present Owner	Where Described
mo- erric atrix	Tiffany & Co., New York	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249
ning anic rtite old,	Do. Do. Do.	Eng. & Min. Jour., 50 (1890), 686 Bull. G. S. A., 2 (1891), 638 Min. Res. U. S., 1892 (1893), 759
clay,	Do.	Am. Geol., 14 (1894), 31 N. J. B., 1896, II, 249 Min. Res. U. S., 1893 (1894), 682
atrix	Widow of L. Endlich, Kewaskum, Washington Co., Wis.	Am. Geol., 14 (1894), 31 Bull. Univ. Wis. (Sci.), 1 (1895), 152 18th Ann. Rept. U. S. G. S., Pt. V, 1183
		16th Ann. Rept. U. S. G. S., Pt. IV (1895), 596
	Bunde & Upmeyer, Milwaukee	18th Ann. Rept. U. S. G. S. (1897), Pt. V, 1183
	Do.	Do.
	Herman Keck, Cincinnati	Not yet described

DISTRIBUTION OF THE LAKE DIAMONDS

The localities at which the diamonds have been found are .istributed throughout an area nearly six hundred miles in ength by two hundred miles in breadth, with its longer axis rending almost exactly northwest and southeast. Six of the :ight localities are near the center of this territory, within an ırea about two hundred miles square, with its center near the :ity of Milwaukee.

All of the diamonds, with the exception of those from Plum Creek, were obtained from the deposits of glacial drift. The Plum Creek diamonds were obtained from the bed of the stream n immediate proximity to glacial deposits. It is clear, thereore, that the stones must have reached their late resting places n the drift through the agency of the ice mantle, and we should, herefore, study the directions of glacial movement throughout he region to discover the law of their distribution and to glean ny facts that may be within our reach regarding the ancestral ome, or homes, which they occupied before they were carried way by the ice.

The accompanying map of the lake region (Fig. 1) is based n the glacial map of Chamberlin[1], but revised and also extended o the north so as to include the results of later studies. The noraines in the vicinity of Lake Erie have been entered from Leverett's Monograph,[2] and those southwest of Lake Superior rom a map by Todd.[3] The directions of the glacial striæ have been obtained from the works of Chamberlin, Leverett, and Todd already mentioned, and from papers by Lawson,[4] Smith,[5]

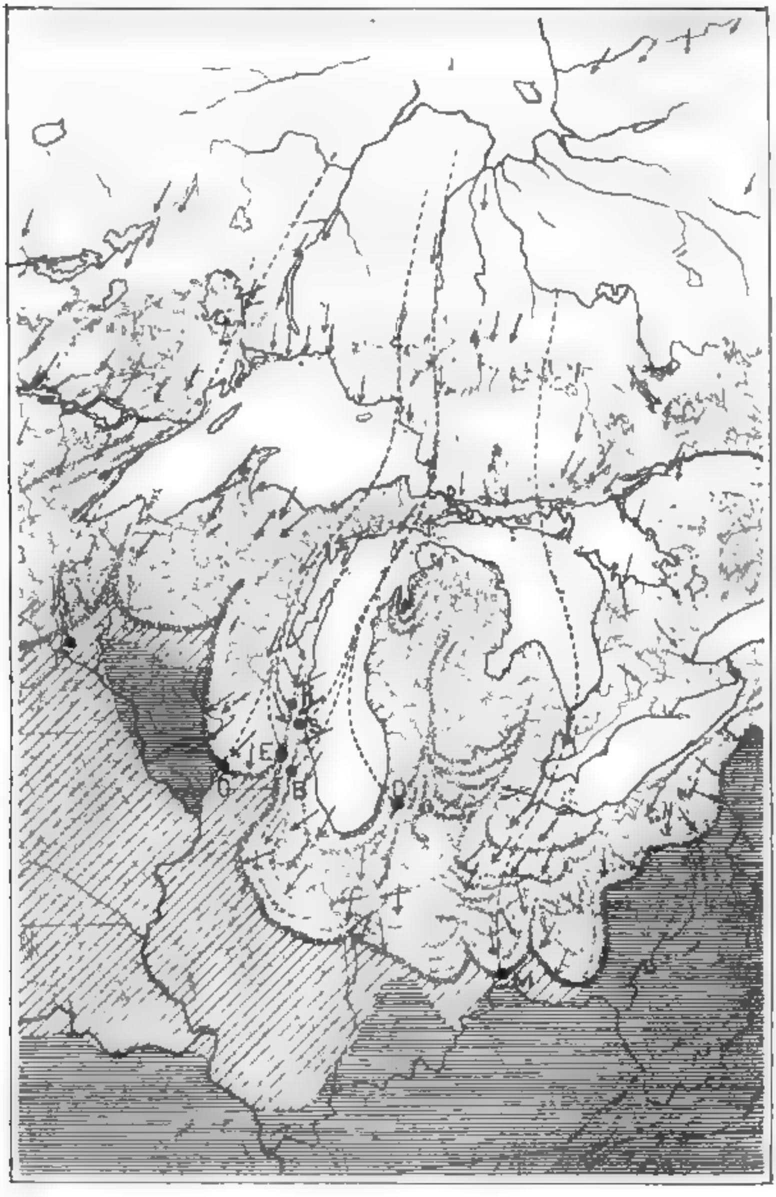
[1] T. C. CHAMBERLIN: The Rock Scorings of the Great Ice Invasions, Seventh nnual Report U. S. Geol. Surv. 1885-6 (1888), pp. 145-248, Pl. VIII.

[2] FRANK LEVERETT: On the Correlation of Moraines and Raised Beaches of ake Erie, Am. Jour. Sci. (3), Vol. XLIII, 1892, pp. 281-301.

[3] J. E. TODD: A Revision of the Moraines of Minnesota. *Ibid.* (4) Vol. VI, 1898, . 469-478.

[4] A. C. LAWSON: On the Geology of the Rainy Lake Region. Geol. Surv. Can., ol. III, 1889, Pt. I, Rept. F, Sheet No. 3.

[5] W. H. C. SMITH: On the Geology of Hunter's Island, and Adjacent Country. *id.*, Vol. V, 1893, Rept. G, Sheet No. 23.



GLACIAL MAP OF THE GREAT LAKES REGION

Driftless Areas — Older Drift — Newer Drift

Moraines — Glacial Striae — Track of Diamonds

Diamond Localities — E Eagle — O Oregon

K Kohlsville — D Dowagiac — M Milton — P Plum Crk — B Burlington

Jpham,[1] Low,[2] McInness,[3] and Bell.[4] In the Ohio area and in ome others where a large number of observations of striæ have een collected the scale of the map has made it necessary to eneralize, but these regions have been so carefully studied, both s regards moraines and scorings, that it was found easy to do his. In fact, within the territory of the United States the data t hand are sufficient for a fairly satisfactory plotting of the gen- ral direction of glacial movement at almost every point. Within he domain of Canada the great wilderness region has been overed only by reconnoissance surveys and except in the territory ordering on the lakes there exist only a few scattered obser- ations from which to construct a map of glacial movement. In he district to the southeast of James Bay some surveys have been nade but the material is not yet in print. In the region south- vest and west of James Bay, which possesses also great inter- st, no data are available. Particularly in this latter region it is ikely that striations will be found corresponding to different peri- ds, owing to the fact that the ice from the Keewatin and Labra- lorean *névés* coalesced within this territory.

By plotting the diamond localities on the map it is seen that ll but the Plum Creek locality are situated on the moraines of he later ice invasion, and that the latter locality is quite near to he moraine, within the area of overwash. It is also worthy of ote that all but the Dowagiac stone were found in one of the arginal moraines which marked the greatest advance of the ice uring its later invasion. The moraine which passes through Dowagiac corresponds to a somewhat later period, during the final etreat of the ice.

[1] WARREN UPHAM: Late Glacial or Champlain Subsidence and Re-elevation of e St. Lawrence River Basin, Am. Jour. Sci. (3), Vol. XLIX, 1895, pp. 1–18. l. I.

[2] A. P. LOW: Report on Exploration in the Labrador Peninsula, Geol. Surv. an., Vol. VIII, 1896, Rept. L, p. 387, Sheets Nos. 585–588.

[3] W. C. MCINNESS: Sixth Report, Bureau of Mines, Ontario, 1896, Sheet No. 9.

[4] ROBERT BELL: Report on the Geology of the French River Sheet, Ontario, eol. Surv. Can., Vol. IX, 1898, Rept. I, pp. 29, Sheet No. 125.

PROBABLE EXPLANATION OF THE DIAMOND DISTRIBUTION

The material from which the diamonds were derived must clearly have been to the northward beyond the lakes, in the wilderness of Canada. A method which may result in locating this material with some definiteness will be elaborated below. To explain the occurrence of so large a proportion of the stones in or near the outermost moraine, it is necessary to assume either that at the beginning of the second great advance of the ice the diamonds were embedded in a loose material easily transported, and hence largely removed before the stages of retreat, or that they were embedded in their matrix, which from its limited extent was largely abraded and removed by the ice during its initial stage.

The first is the more reasonable assumption, by reason of the wide fan of distribution of the diamonds, and the number which has been found warrants the assumption that the number of stones at the source of supply must have been very considerable. It is likely that for every diamond that has been found there are a thousand still undiscovered in the drift.

Professor T. C. Chamberlin has, at my request, very kindly given me his views on this question, and I have his permission to print the following from a personal letter:

In regard to the explanation of the occurrence of the diamonds in the large moraines near the outer limit of the later invasion two explanations present themselves: First, the diamonds were separated from their original matrix in preglacial times by disintegration and accumulated in the bottoms of the valleys in the vicinity of their origin. The first glaciations were not sufficiently abrasive to remove the diamond-bearing gravels in the bottoms of the valleys, or at least not able to do so completely. The diamonds, therefore, do not occur frequently in the earlier drift material. Furthermore, the earlier drift material was less subjected to wash and now appears less abundantly as clean gravel and hence a less proportion of the diamonds that may have been embraced in it have been found. The chances of finding diamonds scattered throughout the till is of course relatively small.

The second hypothesis postulates a sufficient interval between the earlier glacial invasion and the later to permit the disintegration of the diamond-bearing matrix and the freeing of the diamonds which became subject to transportation and accumulation in the wash from the moraines of the later drift.

This view also supposes that the glacial abrasion directly freed some of the diamonds.

Of course the two hypotheses might be conjoined and this would be reasonable enough if the diamond-bearing matrix were such as to be topographically protruding and be subjected to disintegration and wear during the interglacial interval.

Of the two hypotheses, I incline somewhat to the first, as I think it more likely that the diamonds would be accumulated in some notable quantity in the long preglacial period of disintegration than in the relatively short interglacial interval.

To me also it seems that the former hypothesis is the more probable one, for the reason given, and further, because, as will be seen from what follows, the broad fan of distribution of the diamonds would seem to require a somewhat extensive area of supply, unless it be assumed that this was very near to the "center" from which the ice moved.

THE ANCESTRAL HOME OF THE DIAMOND

The problem of locating the area from which the diamonds of the drift have been derived is a fascinating one, and, while the data now available are insufficient for its complete solution, they are of a kind to indicate that, with the increase of our knowledge likely to come in the next decade, the desired end may be reached.

The first question which naturally arises is whether all the diamonds that have been found in the lake region have been derived from a common source. While there is no certain evidence that they have, nevertheless it would seem to be probable. Diamond-bearing rocks are not so numerous that there is much likelihood of two unconnected areas being discovered in the region in question. Moreover, the occurrence of diamonds with somewhat similar crystal habits over so large a territory would seem to be significant. The Oregon, Eagle, and Kohlsville diamonds, since they were found in the Green Bay lobe of the ice mantle, a comparatively narrow area, must certainly be regarded as having a common source, and this must be, as the writer pointed out in 1894, either on the medial line of the lobe,

or still farther away to the northward. It is also fair to suppos that the Saukville, Burlington, and Dowagiac stones, thoug they differ from one another in habit as much as any three stone from the region, have also a common source, since they wer located comparatively near to one another in the moraines o the Lake Michigan lobe. Of these latter, the Dowagiac diamon is a hexoctahedron, like the stones from Plum Creek and th closely related vicinal hexoctahedrons of Eagle and Kohlsvill

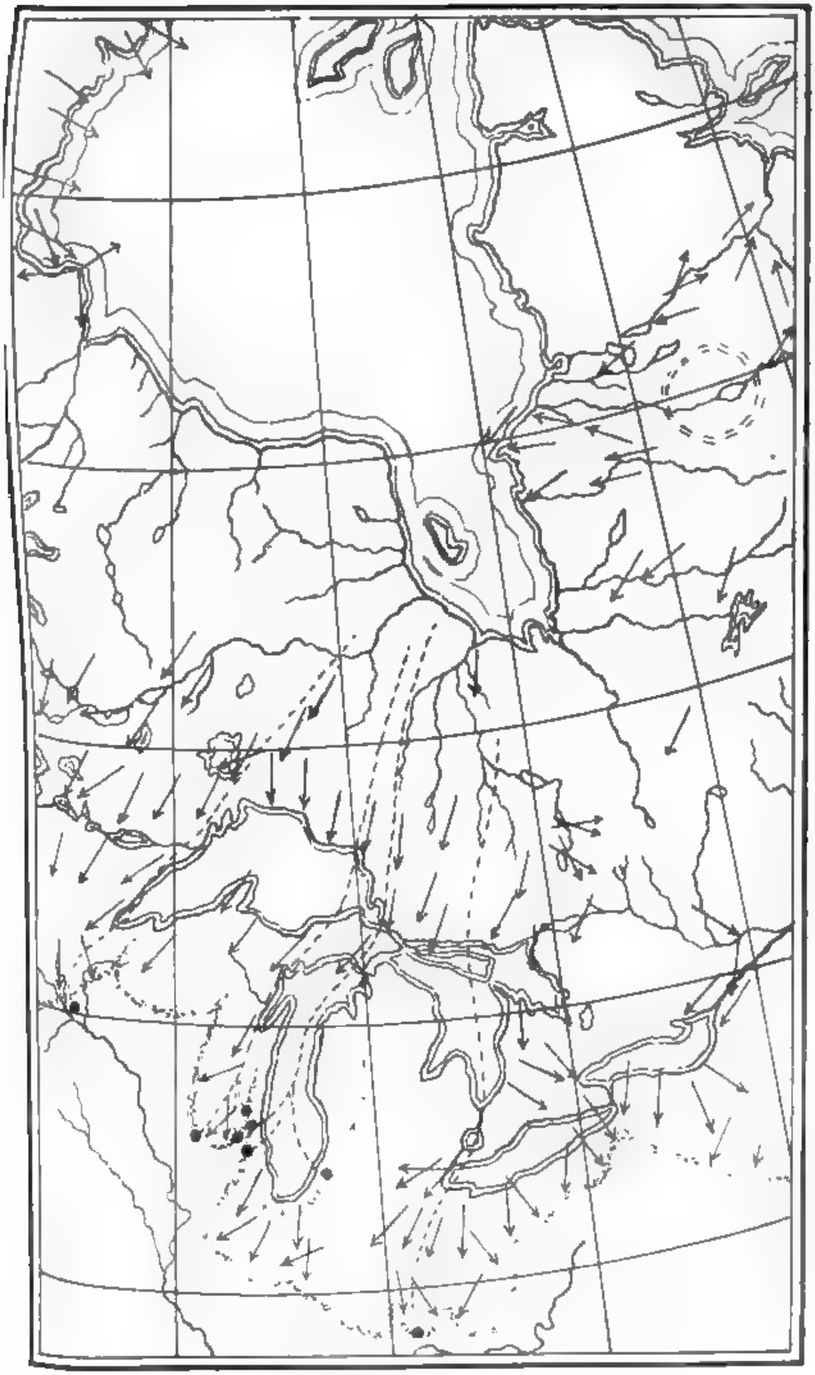
Provided a common source is assumed for all the diamond of the region, this can only be located at the apex of the fan o diamond distribution on the hither side of the névé from whic the ice moved. The wider this fan of distribution is found t be, the nearer is its apex carried towards the ice summit. Th radial sides of the fan must be largely determined from th directions of striæ within the Canadian wilderness, of which a adequate number have been recorded only from the immediat vicinity of the Great Lakes. Beyond these borders the *trackin* of the diamonds can be carried out only with a certain approx imation to correctness.

One of the results of the magnificent investigations of Tyrrell and Low,[2] the one working to the west and the other to the eas of Hudson Bay, has been the location of two main "centers of the ice mantle corresponding to the Keewatin and Labrador can or Laurentide glaciers. The eastern of these "centers" o névés, and the one which must have principally affected th glaciation of the area of the Great Lakes, has been located b Low to the east of James Bay, a little to the eastward of th present watershed on the Labrador peninsula. This is brough out on the accompanying map (Fig. 2) by the directions of th striæ of this vicinity.

The tracks of the lake diamonds which have been delineate upon the map, converge in the direction of this névé, and sho

[1] J. B. TYRRELL: Report on the Doobaunt, Kazan, and Ferguson Rivers, and th northwest Coast of Hudson Bay, Geol. Surv. of Can., Vol. IX, 1896, Report I pp. 1–218.

[2] A. P. LOW: *loc. cit.*



GLACIAL MAP OF THE TERRITORY ABOUT HUDSON BAY AND THE GREAT LAKES.

that the apex of the fan of diamond distribution probably lies somewhere in the strip of territory bordering James Bay on the east.

DATA NEEDED TO DEFINITELY LOCATE THE SOURCE OF SUPPLY OF DIAMONDS

Before the home of the diamonds can be located with definiteness, it will be necessary to carry out several lines of investigation. Of first importance is it that the direction of ice movement be studied in as much detail as possible in the territory surrounding Hudson Bay on the southwest, south, and east. It will be important also to search the moraines south of the lakes, and particularly the marginal ones, for diamonds, since the evidence points to them as the principal repository of the emigrated stones. It is especially important to examine the moraines of Ohio, western New York and western Pennsylvania, in order to determine whether the fan of distribution extends farther in that direction. If this is true, the apex of the fan would seem to be located very near to the center of the Labradorean névé.

It has seemed to the writer that much might be gained by arousing an interest in the problem in the people who reside on or near the moraines, and suggesting to them that children particularly be urged to use their keen eyes in search for the diamonds that have been sown in the drift. To this end a brief statement has been prepared which sets forth what has already been learned regarding the lake diamonds, and explaining how rough diamonds may be distinguished from the ever present quartz pebbles. For identification of stones the persons finding them are referred to mineralogists, who are competent to pass upon gem stones, and who are willing to do so without compensation because of their interest in the problem. It is hoped that the editors of local newspapers in the morainal belt, to whom the statement will be mailed, will be willing to coöperate by printing it, and thus aid materially in disseminating the needful information.

WM. H. HOBBS.

REPLACEMENT ORE DEPOSITS IN THE SIERRA NEVADA

It is well known that most of the gold deposits of the Sierra Nevada occur in true fissure veins in which the quartz appears to have been deposited in open cracks. This has been emphasized recently in a very clear manner by Mr. Waldemar Lindgren in two papers,[1] and he has also shown that the material of these veins was deposited by carbonated waters containing also silica and the precious metals. These waters have deposited their carbonates in very definite zones in the wall rocks, and the silica in the fissures. At some points, however, in the Sierra Nevada there are ore deposits which seem to have formed by the replacement of other material. Such appears to be the Diadem lode[2] southwest of Meadow Valley in Plumas county. This lode seems to represent a mass of dolomite and lime carbonate which has been replaced by quartz and chalcedony; masses of dolomite are still found on some of the levels. Iron and oxides of manganese are present, and according to J. A. Edman rich selenides of gold and silver combined with lead and copper occur as a rarity. Some of the manganese is in the form of the silicate, rhodonite. A certain portion of the lode is composed of little elliptical bodies which according to Mr. Charles Schuchert of the U. S. National Museum represent the silicified tests of foraminifera of Carboniferous age belonging to the genus Loftusia. The shells of Loftusia were originally carbonate of lime. These fossils were found by Mr. J. A. Edman, the proprietor of the mine, and forwarded to the Geological Survey for determination. They sometimes form considerable bunches, the interspaces between the elliptical tests being filled with secondary silica, or in some

[1] Bull. Geol. Soc. of America, Vol. VI, pp. 221-240.

Gold Quartz Veins of Nevada City and Grass Valley, Seventeenth Ann. Rep. U. S. Geol. Surv., Part II.

[2] See Bidwell Bar folio of the U. S. Geol. Survey.

cases being open. Other specimens of a fine-grained red siliceous rock which forms part of the lode, appear to represent a calcareous shale subsequently silicified. The red rock contains very abundant bodies, smaller than the Loftusia determined as such, but probably also of foraminiferal origin. Whatever the original nature of these smaller tests, they are now composed of granular quartz like the Loftusia. There is here unequivocal evidence that a considerable mass of carbonates has been replaced by silica. A large portion of the vein material containing the precious metals of the Diadem lode is chalcedony. The same waters which deposited the quartz and chalcedony and replaced the carbonates of the foraminifera tests are without doubt responsible for the gold, silver, manganese, etc., found in the deposit. This vein deposit may therefore be called a replacement deposit. The Diadem lode lies in the fault zone along which displacements have formed the steep slope east of Spanish Peak. There is also evidence of faulting in comparatively recent times at the lode itself.[1] It is without doubt along these faults that the waters containing the silica, etc., of the deposit have found their way from below. Such being the case it is likely that a certain portion of the secondary material may represent a true vein deposit, but it is probable that the larger part of the lode, which is represented by Edman as being in places sixty feet wide, may be called a replacement.

Professer Whitney inclined to the belief that the great quartz veins of the mother lode represent the replacement of bodies of dolomite. As Lindgren remarks,[2] however, this theory has not been supported by more detailed investigation. H. W. Fairbanks has suggested that these very large veins of pure quartz, sometimes forty feet in width, have resulted from the replacement of dikes of basic igneous rocks. The mechanical difficulty of accounting for the existence of such wide fissures, and the fact that the vein matter in these large masses seldom shows a banded structure such as might be expected from the deposit of

[1] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 553.

[2] Bull. Geol. Soc. Am., Vol. VI, p. 235.

successive layers of quartz in an open space, are urged by Fair banks as difficulties in the way of calling these veins filled-in fissures. The gradual replacement of the constituents of dike rocks by the vein material would perhaps account for the great size of the veins as well as their lack of banded structure. However, quite recently Lindgren[1] has brought forward a point as to the different character of the silica deposited as replacement material by a metasomatic process and that deposited in open spaces, which may serve as a criterion to determine, with the aid of the microscope, the two classes of deposits. Lindgren, after referring to the strong solvent nature of carbon dioxide and of alkaline carbonates, and the inert character of silica as a solvent, writes:

Silicification by the cementation of shattered rock masses by silica is, of course, a common occurrence in and near quartz veins. But silicification by replacement is a less common process, and is observed chiefly in the case of easily soluble rocks. such as limestone or calcareous shales, when it results in fine-grained or cryptocrystalline aggregates of silica. In the metasomatism of bodies of massive rocks penetrated by chemically active solutions silica is formed in many ways, as by the carbonatization of silicates and sericitization of the feldspars, and if no open spaces are available much of this free silica will be deposited within the rock, usually as fine-grained aggregates more or less mixed with opal and chalcedonite. If no material were added the final result of this would not, however, be a silicification, but merely an increase in the total free quartz of the rock. But in case the rock mass is cut by fissures it appears that most of the resulting free silica is not deposited in the rock, but finds its way out in the open ducts, where, if the solution is supersaturated, it will be deposited. . . . . . .

As for the other possible process of silicification, or a dissolving of the original mineral and a deposition of silica *pari passu*, it occurs chiefly in easily soluble minerals, such as calcite. In case of the ordinary rock-forming silicates it is apparently not common. The resulting silica is generally in the form of fine, cryptocrystalline aggregates. Rocks silicified by either of these metasomatic processes, or by a combination of both, may occur, but, so far as the writer's experience goes, are not often encountered as wall rocks of auriferous quartz veins. But neither of these processes can have produced the massive, white, coarse-grained quartz of gold veins belonging to the normal type. This quartz, which contains native gold and sulphides, shows,

[1] The Mining Districts of the Idaho Basin and the Boise Ridge, Idaho, Eighteenth Rep. U. S. Geol. Surv., Part III, p. 645.

under the microscope, a peculiar, coarsely granular structure, the grains being partly bordered by crystallographic surfaces. This structure could have been developed only by free crystallization in open spaces. It is scarcely necessary to call attention, in addition, to the frequency of comb structure, etc., proving also the same kind of origin. This does not necessarily mean that all large bodies of quartz have been deposited in an open space, as large as the volume of quartz now is. Repeated openings of the fissure have doubtless often taken place.

Lindgren's results as to the usually finely granular character of the quartz deposited as a replacement are borne out in the Diadem lode occurrence, as may be seen by an inspection of Plate V on which are represented two photomicrographs, one of a thin section of the red siliceous rock of the Diadem lode without the analyzer, in which may be seen the outline of one of the elliptical bodies previously referred to as being probably of organic origin, and the other exactly the same view with the analyzer, in which the finely granular character of the quartz is shown. No careful microscopic examination of the quartz of the large massive veins of the southern part of the lode has, so far as I know, been made. Three thin sections from the croppings at the Peñon Blanco mine in Mariposa county (see Sonora folio) show that considerable patches of the quartz have the same optical orientation throughout, indicating large crystals and consequently deposition in an open space. It appears, therefore, likely that the huge quartz masses, some of them twelve meters in width, were deposited in open fissures and are not replacement deposits. The large size of the masses of quartz having apparently the same optical orientation throughout and the lack of banding may indicate merely quiet conditions during deposition and lack of interruption of the process.

To certain masses that form portions of the Mother lode a somewhat different origin must be assigned. I refer to the oft-described deposits composed of quartz, and calcium and magnesium carbonate, and mariposite. Lindgren considers[1] that these large masses represent nothing but altered serpentine, and asserts that abundant transitions may be found to prove this, as may

[1] Bull. Geol. Soc. Am., Vol. VI, p. 235.

›e plainly seen at the App mine at Quartz Mountain in Tuolumne :ounty. He considers this conversion readily explained when t is considered that serpentine is easily decomposed by carbon- ıted waters into magnesite and chalcedonic quartz. In this :ase, as with the fissure veins, the essential feature is the intro- luction of the carbonated waters, and in confirmation of this nay be cited the composition of this peculiar alteration product ıs given later in the table (Analysis No. 1508). The atomic com- ›osition of this rock is quite similar to the atomic composition of ›erpentine with the addition of carbon dioxide; while the lifference in mineral composition is very striking, the original ›erpentine being a silicate and the alteration products carbonates. Such a deposit cannot be called a vein and it is likewise from he above standpoint not a replacement deposit, for the original :lements are largely still there but in new combinations. There ıre some facts which will now be presented which at first glance ›uggest that the quartz, carbonate and mariposite deposits above lescribed have not originated from the alteration of serpentine n place, but have resulted from the metasomatic alteration of likes rich in soda, and hence may be called replacement leposits.

Lying just east of Moccasin Creek[1] in Tuolumne county, is ı white dike which extends from the mouth of the creek in a ›outheasterly direction. The larger portion of the dike lies :ast of the creek and crosses the road to Priest's about 0.6 kilo- neters east of the bridge over Moccasin Creek. This dike has ›een rather fully described in a previous publication.[2] It is com- ›osed largely of soda-feldspar or albite, with quartz and musco- vite locally abundant. A green aegerite-like mineral, and radial :ufts of bluish amphibole are likewise present at some points. Throughout the greater part of its course the dike is bordered by serpentine on the west and greenstone on the east.

At numerous points this dike has been exploited for gold. Some of it is plainly mineralized, containing specks of iron

[1] See Sonora folio of the Geological Atlas of the U. S.

[2] Seventeenth Ann. Rep. U. S. Geol. Surv., Part I, p. 664.

pyrite. The rock is often very white and hard and is called quartz by some of the miners who are exploiting it. Three samples of this soda-feldspar dike from the Wheeler and Hill claim were assayed with the following results:

ASSAYS OF THE SODA-FELDSPAR DIKE OF THE WHEELER & HILL CLAIM

	2005 A	B	C
	Ounces	Ounces	Ounces
Gold	0.10	0.02	none
Silver	0.15	0.12	none
Authority	C. E. Munroe	Selby & Co.	Selby & Co.

The gold and silver and the iron pyrite appear to be disseminated through the dike rock, for no little veinlets are to be noted in the specimens assayed, as is the case in some of the mineralized soda-feldspar dikes. At the Black Warrior mine on the Moccasin Creek dike there has been reported a valuable deposit of workable ore since the date of my visit (1897). In the tunnel of this mine a mineralized talc streak in serpentine contains sulphides of iron and gold and silver. As to whether the valuable ore body is in the dike rock or not I have no reliable information.

Along Kanaka Creek about 2 km east of Jacksonville is another soda-feldspar dike which is nearly in a line with that east of Moccasin Creek. This is likewise mineralized at several points. At the Willietta mine on the Kanaka Creek dike a considerable mass of the dike rock has been quarried out and treated as ore. This deposit was examined by a San Francisco mining engineer, Mr. Luther Wagoner, and I am indebted to him for the following information: About 3000 tons of the rock were milled; the top two or three feet of the dike yielding about $3 per ton. Subsequently Mr. Wagoner made a mill test of a face fifteen feet high, this containing about 78 cents per ton in gold. Another sample of thirty tons yielded 56 cents per ton in gold. The concentrates (probably chiefly iron pyrite) were found to

be quite poor, showing only about \$14 per ton. The gold seems to lie largely along the seams and joints of the mass. The unweathered dike rock carries about ½ per cent. of pyrite in little cubes from 0.5 to 1 mm in diameter.

In Eldorado county similar dikes form the lodes of gold deposits. Two of these have been worked with some profit.[1] The claims are known as the Shaw and Big Canyon (Orofina) mines, and are indicated on the economic geological map of the Placerville folio. My attention was first called to the Shaw mine lode by Mr. Leo von Rosenberg who transmitted specimens of the rock showing the porphyry dike rock, and other specimens containing veins of quartz and veins of albite with free gold. The dike rock of the Shaw mine and also that of the Big Canyon mine contain iron pyrite rather abundantly in places. Calcite is scattered through the dike rock in little rhombs. The evidence at the Shaw and Big Canyon mines is that mineral waters have percolated through the dike rock and deposited the iron pyrite and calcite with some gold throughout portions of the dike, while the quartz has largely been deposited in little veins along with most of the gold. The veins of white albite in the Shaw mine rock are undoubtedly secondary, but probably represent the material of the dike leached out and redeposited. This in itself suggests that albite is a mineral which is readily dissolved, and Lindgren has found sodium one of the elements most readily removed from the wall rocks of quartz veins.

The Bachelor lode on the north bank of the Tuolumne River lies at the contact of a mass of serpentine with a lens of argillite supposed to belong to the Calaveras formation. Just east of the vein, in the clay schists within a width of thirty feet, are six or eight dikes, which usually run parallel with the strike of the schists, but at two points cut across the schistosity. Such a series of dikes might be called a multiple dike, following

[1] Am. Jour. Sci. Third Series, Vol. XLVII, 1894, pp. 470–471.

Engr. and Mining Jour., Nov. 19, 1892, article by C. A. AARON on the Shaw mine lode.

Am. Geol. Vol. XVII, 1896, p. 380.

KEMP, Ore Deposits of the U. S., New York 1896, p. 287.

Lawson,[1] as it is reasonably certain that at some depth below the surface they all come together. The dikes vary from two inches to two feet in width. Quartz veinlets, one with a convoluted course, cut both the schists and the dikes. Between the dikes and the ledge is a broken-up mass of the dike rock of a reddish-brown color, penetrated by quartz veinlets and seams of dolomite, and apparently in a fair way to form a lode, like that immediately west, if the alteration should go farther. This mass seemed a friction breccia and would indicate movement and faulting along the lode. A microscopic examination of this breccia showed it to be made up of fragments of the dike rock cemented by dolomite and quartz. Throughout the rock, as well as in the dikes just east, is scattered iron pyrite in minute specks. The brown color is due to abundantly disseminated limonite. The microscope shows the dike rocks, where not replaced by silica and carbonate, to be composed almost entirely of interlocking grains of soda-feldspar with some larger twinned feldspars, in fact identical as to composition with other similar soda-feldspar dikes. There thus seemed to be evidence here that the dike rock has undergone replacement. To determine what alterations had taken place in the dikes some partial chemical analyses were made as follows:

PARTIAL ANALYSES OF SODA-SYENITE AND ITS REPLACEMENT ALTERATIONS BY DR. H. N. STOKES

	No. 1521	No. 1509	No. 1512	No. 1508
SiO_2	67.53	52.83	42.48	37.58
$CaCO_3$	none	9.64	13.43	5.78
$MgCO_3$	none	7.38	8.17	46.82
$FeCO_3$	none	.98	5.88	6.35
FeS_2	....	.77	.40	none
K_2O	.10	.35	2.67	0.23
N_2O	11.50	7.87	4.79	trace
Residual CO_2	none	.59	2.23	2.45

[1] American Geologist, Vol. XIII, p. 293.

Dr. Stokes states that the residual CO_2 is the excess above that required for $CaCO_3$ and $MgCO_3$, and is in 1508 at least clearly present as $FeCO_3$. Assuming the residual CO_2 is in the form of $FeCO_3$ in 1509 and 1512 also, I have calculated the amount of this in each case and inserted it in the analysis. The analysis as completed by Dr. Stokes contained no estimate of the $FeCO_3$.

No. 1521 is a specimen of the Moccasin Creek dike, and composed of nearly pure soda-feldspar. The rock contains no carbonates.

No. 1509 is from one of the soda-feldspar dikes in argillite just east of the Bachelor mine deposit.

No. 1512 is a more altered specimen of the soda-feldspar rock from another branch of the multiple dike of the Bachelor mine.

No. 1508 is the Bachelor lode material itself, composed of quartz, carbonates, and mariposite.

In this series there is the clearest evidence of a diminution of silica and sodium and an increase of carbonates from the fresh dike rock represented by No. 1521 to the lode material represented by No. 1508. There is, however, a decided jump in the magnesian carbonates in Nos. 1509 and 1512, which are certainly altered soda-feldspar dikes, to the magnesian carbonate in the lode material 1508. There being a mass of serpentine immediately west of the lode, and magnesium being readily soluble in carbonated waters, no one will doubt that the magnesium, both in the lode and in the dikes, came orginally from the serpentine. The possibility therefore arises that the association of the dikes and the carbonate lode is merely accidental. In that case we are forced to adopt Lindgren's hypothesis as to the origin of the lode itself, and to suppose that the alteration of the dikes is merely due to its proximity to the lode, itself formed by the alteration of serpentine. A case entirely similar is that of a mass of shale adjacent to serpentine. An analysis of the shale next to the serpentine may show a decided content of magnesia, but this does not prove the origin of the serpentine from the shale, but merely that waters charged with magnesium

from the serpentine have soaked into the shale and deposited their burden.[1] The above facts cannot be regarded as evidence that the Bachelor lode has formed from the replacement of a soda-feldspar dike, but it gives conclusive evidence that such dikes readily undergo replacement when permeated by mineral waters. The soda-feldspar dikes occur very often in association with serpentine. This is the case in Plumas and Butte counties, where, however, no evidence of mineralization was noted. It is also the case at the Big Canyon mine, Eldorado county, and at the Willietta, Bachelor, Black Warrior, and Wheeler and Hill mines in Tuolumne county, and at various points north of the Merced River in Mariposa county. The dikes are not confined to the serpentine, however, although, so far as I know, they are nearly always in the neigborhood of this rock. One dike, however, more than a kilometer in length was noted in the sediments of the Calaveras formation, the nearest mass of serpentine being four kilometers distant. Open cuts at numerous points indicated that this dike had been prospected for gold. There is also a syenite dike in the slates of the Mariposa formation by the tollhouse west of Princeton, along which are small quartz veins. This dike is likewise mineralized, containing lime carbonate very abundantly and pyrite. At the Shaw mine also the dike is in slates, probably of Carboniferous age. The usual association of the dikes with serpentine suggests an original genetic connection,but this has nothing to do with the mineralization of the dikes, which takes place irrespective of the immediate presence or absence of serpentine, although it is possible that magnesium carbonate is never present to any extent except when serpentine is immediately adjacent. The association of gold with soda-feldspar dikes, so far as my observation goes, is more frequent than with dikes of other rocks, and this may point to albite being a mineral more readily altered or replaced by mineralizing solutions than any other feldspar. Experiments have been made on the relative solubility of some of the feldspars in pure water and in water charged by carbon dioxide. Mr. George Steiger kept for one month one half grain

[1] For definite examples of this see Bull. Geol. Soc. Am., Vol. II, pp. 406–408.

of three powdered feldspars separately in 50 cm^3 distilled water, at 70° F., with the following results:

	Percentage of alkali dissolved
Orthoclase - - - - - - - - -	0.16 K_2O
Albite (Amelia Co., Va.) - - - - - -	0.07 N_2O
Oligoclase (Bakersville, N. C.) - - - - -	0.09 N_2O

This would show a greater solubility for orthoclase than for albite, but it is more to the point to observe the relative solubility of the feldspars with water charged with carbon dioxide. R. Müller[1] obtained the following results:

SOLUBILITY OF METAL OXIDES OF FELDSPARS IN CARBONATED WATER

	SiO_2	Al_2O_3	K_2O	N_2O	CaO
Orthoclase (Adular)	.1552	.1368	1.3527	....	trace
Oligoclase	.237	.1713	....	2.367	3.213

It is clear here that the soda of the oligoclase is more soluble than the potash of the orthoclase, and that the lime of oligoclase is more soluble than the alkali. No quantitative statement of the solubility of pure albite in carbonated waters has been noted. The apparent readiness with which the albite of the dike rocks described in the paper goes into solution and is again deposited as albite in cracks, seems certainly to indicate that under certain unknown conditions this mineral is readily soluble.

Dr. Becker[2] describes the Treadwell mine on Douglas Island in Alaska as being an impregnation of a dike of sodium syenite, which has been mineralized in apparently exactly the same way as the sodium syenite dikes of the Mother lode above described. Becker states that the Treadwell syenite is composed chiefly of albite with subordinate amounts of soda-lime-feldspar, augite, amphibole, and biotite.

The ore associated with the syenite is separable into two distinct varieties. Of these one consists of stringers of quartz carrying some calcite and occupying interstitial spaces between more or less decomposed syenite fragments.

[1] Braun's Chemische Mineralogie, 1896, p. 398.

[2] Eighteenth Ann. Rep. U. S. Geol. Surv., Part III, p. 38 and p. 64.

In such ore the pyrite is often grouped in bunches and at other times is disseminated through the quartz. The distribution of the pyrite seems to be without effect upon the tenor of this variety of ore, which is usually rich in proportion to the quantity of pyrite. The other variety of ore consists of fragments of the syenite which have been, as it were, *soaked* in the auriferous liquid. They are impregnated chiefly with carbonates and pyrite, only a little silica penetrating where there were no open fissures. The pyrite in this variety is also either bunched or disseminated, and all the mine foremen assert that where this pyrite is scattered, the ore is nearly or quite worthless. It appeared to me that the disseminated pyrite represents ferromagnesian silicates attacked by sulphydric acid or soluble sulphides, and study of the ore under the microscope lends strength to this hypothesis, though without absolutely proving it.

Wherever the ore is strongly mineralized the ferromagnesian silicates have totally disappeared from the syenite, and the pyrite is scattered in it in about the same manner as the iron-bearing silicates in the fresher material. On the other hand, as the bunches of pyrite are accompanied by much calcite they could not have been produced from any ordinary accumulation of ferromagnesian silicates, and I think such pyrite must have entered the rock in a state of solution.

The alteration of the soda-feldspar dikes seldom or never goes so far as to constitute a complete replacement of the original material, and the ores are, so far as I know, uniformly of low grade. Such ore deposits may perhaps be called *partial replacements*. According to Lindgren[1] the term *substitution* is sometimes used for deposits of this character. In a paper on the auriferous veins of Meadow Valley[2] Lindgren describes the alteration of granodiorite along fractures by solutions containing heavy metals and boron. The deposits consist of epidote, zoisite, pyroxene, tourmaline, quartz, mica, titanite, ilmenite, calcite, and auriferous sulphides. These lodes seem to be of the nature of replacements.

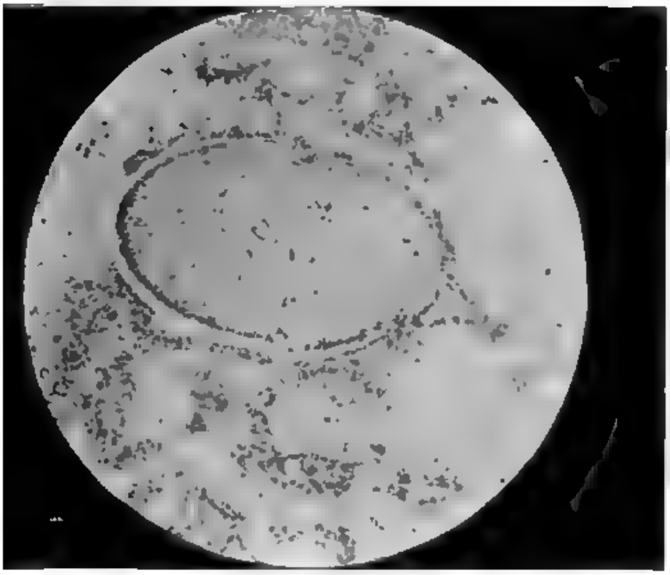
H. W. TURNER.

PLATE.

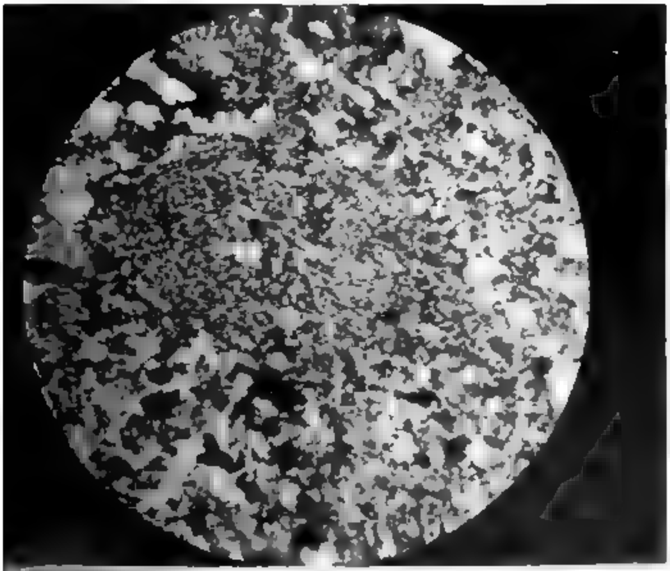
A. Photomicrograph [illegible] section of the red silicified shale of the Diadem lode [illegible]miniferal test, without the analyzer, X 20.

[illegible] thin section of red silicified shale of [illegible]

[illegible]98, p. 10.



A × 29.



B × 29.

EDITORIAL

OTHNIEL CHARLES MARSH has left for himself as conspicuous name and fame as could be desired by the most ambitious ıdent of science. He had the advantages of a strong constitu- ›n, a clear intellect, indefatigable industry, a liberal fortune, a ve of nature and the beautiful, a single purpose, and had no ıe dependent upon him for a share of his devotion. He began e in Lockport, New York, in October 29, 1831; as a boy was nd of hunting and fishing and out-door life; went to Phillips ndover Academy in 1852, graduated in Yale College in 1860, d took two more years of graduate work in the Sheffield Scien- ic School. In those days he was chiefly interested in chem- ry and mineralogy. Then he went to Europe, where he spent ree years studying mineralogy and paleontology, and in 1866 ıs appointed professor of paleontology in Yale University. om that time to the day of his death, March 18, 1899, he was voted to original research, chiefly in the accumulation and udy of fossil vertebrates, and to the building up of the Peabody useum at Yale University, to which he gave at the close of his e all his collections and the great bulk of his fortune.

The contributions Professor Marsh made to science during s busy life are chiefly remarkable for the large number of artling new types of fossil vertebrates which he either first nnounced or brought to conspicuous notice by the number and erfection of the specimens representing them. His earlier nvestigations were in the Cretaceous deposits of the East; but is most remarkable discoveries were in the Jurassic, Cretaceous, nd Tertiary beds of the Rocky Mountain regions, and in the lains east of them. In this latter region he conducted several cpeditions of Yale students or graduates; and after the fossil- aring beds were discovered, employed many collectors for

repeated years in digging out and shipping to the East the immense and rare bones, which were carefully worked out after reaching the Museum.

A bare list of the more important types of vertebrates, which he either first discovered or first elaborated, is of itself enough to exhibit the great place his labors must occupy in the progress of science.

In 1862, he announced the discovery of the Enaliosaurus in the Carboniferous rocks of Nova Scotia—a large Amphibian with biconcave vertebræ. It was Marsh who, in 1868, disputed the organic nature of Paleotrochis; and in the same year the metamorphosis of the Siredon was described. Fossil birds were discovered in both Tertiary and Cretaceous rocks, in 1870. The Rocky Mountain expedition of 1870 resulted in the discovery of the *Mauvaises Terres* formation in Colorado. In 1871, fossil serpents were reported from the Tertiary deposits of Wyoming, and a gigantic Pterodactyl from the Cretaceous of Kansas. In the following year Hesperonis, the wonderful bird with teeth, was announced, and the skull and limb bones of the Mosasaurus, the skeleton of Tinoceras, and remains of Quadrumana from the Eocene of Wyoming described. In 1873, new species of Ichthyornis, another toothed bird, were described, and a new subclass, Odontornithes, was founded, establishing the link between Birds and Reptiles. And the new order Dinocerata, with many enormous species, was defined and elaborated. In 1874, another expedition was conducted to the Rockies, and the Brontotheridæ were fully defined, and the fossil horses and their ancestors of the Tertiary were described. Also, a paper was written illustrating the small brain capacity of the early Eocene mammals. In 1875, a new order of Eocene mammals was announced, and an important statement of the affairs of the Red Cloud agency was made to the President.

In the following year the characters of the Dinocerata, the Tillodontia, the Brontotheridæ, the genus Coryphodon, and a new suborder of Pterosauria, were elaborated in important papers. In 1877, wonderful Dinosaurs from the Jurassic were

brought to light; and in 1878, new species of Ceratodus, of Dinosaurs, and of Pterodactyles were described. The next year he described another new order, the Sauranodonta from the Jurassic of the Rocky Mountains, and wrote the paper on Polydactyl horses, recent and fossil, setting forth in brief the history of the horse ancestry. The monograph on the Odontornithes was published in 1880. Numerous papers followed as the great and peculiar types of Dinosaurs were worked out; the Stegosaurus, the Brontosaurus, the Ceratopsidæ, Triceratops, etc.; and in 1896, an elaborate report on the Dinosaurs was published as a part of the Sixteenth Annual Report of the United States Geological Survey, not in the form of a monograph. In 1884. the skull of Pteranodon, the Pterodactyl without teeth, was elaborated, and the monograph on the Dinocerata, the gigantic extinct order of mammals, was published.

During the last ten years of his life, although there were fewer great discoveries to announce, the papers in elaboration of the immense accumulation of materials illustrating fossil vertebrates appeared in rapid succession; over one hundred titles having been added to the list of his published papers during these years. Among the more important contributions during this period were his discussions of the relations of *Pithecanthropus erectus;* on the age of the beds on the Atlantic coast which he called Jurassic; and important additions to knowledge of Dinosaurs, Tertiary and Cretaceous mammals, birds, fossil footprints; the description of a new Belodont reptile from the Connecticut River sandstone; and on sundry other subjects.

Professor Marsh was honored by election to membership and office in the principal societies and academies devoted to science in this and other countries. He was for two terms President of the National Academy of Sciences, and in 1897 received the Cuvier prize from the Institute of France. In 1886, he received the honorary degree of Ph.D. from the University of Heidelberg.

He died in the midst of active work. The manuscript for several other monographs on fossil vertebrates was left unfinished. Besides the large collections accumulated at his own

expense, which he had turned over formally to Yale University before his death, he left a large amount of material belonging to the United States Geological Survey, which had been collected under his direction and was undergoing description. It is probably true that no other one man has ever accumulated such a vast collection of remarkable and well preserved fossil vertebrates.
H. S. W.

MR. THOMAS JONES has recently completed a reduction of his model of the earth which possesses sufficient merit and is of sufficient interest to geologists to warrant notice. The vertical exaggeration of his former globe was 36 to 1. The present is a reduction to 18 to 1. This relieves the exaggeration of most of its objectionable features and still leaves the relief impressive enough for lecture-room purposes. The first copy made has now been in use by the writer for several weeks with satisfactory results. The hypsometric data given by the Challenger Report have been followed for the oceanic basins.
T. C. C.

TO MEET an expressed desire for advanced summer courses in the fundamental principles of geology and glaciology suited to college teachers and advanced students, two courses will be offered during the first term of the summer session, July 1 to August 1, at the University of Chicago by Mr. Chamberlin. The first will consist of a discussion of basal questions and unsolved problems in geology taken up in historical order, so as to constitute in some measure a review of geological history. Following the method of multiple working hypotheses these questions will be discussed in the light of alternative theories. Some special attention will be given to a new series of hypotheses based upon the slow growth of the earth by meteoroidal accretions, these hypotheses being of such a nature as to develop with peculiar facility the strength and weakness of existing hypotheses and

› open up the problems widely. The atmospheric and cli-ıatic factors will receive special attention, as will also the :ciprocal development of land and sea periods, the conditions f expansional, restrictional, and provincial life evolution, and the pecial functions of base-leveling, sea-shelves, epicontinental seas nd atmospheric changes in controlling life progress.

The course in glaciology will embrace a discussion of the ›hysics of glaciers, their chronological development, the dis-inctive phenomena of glacial deposits, and their interpretation.

The two courses will run parallel. They are only offered or the coming summer.

Besides these, the usual courses in physiography, meteorology, general and structural geology and field work will be offered by Professor Salisbury, assisted by Messrs. Goode, Atwood, Cal-houn, and Finch.

ERRATUM

On p. 225 of the current volume, for "The glacier on Mount Iztaccia-huatl is advancing" read: the glacier on Mount Iztacciahuatl is retreating at the rate of about two meters a year. H. F. R.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

SMYTH[2] reports on the crystalline rocks of St. Lawrence county, and particularly the towns of De Peyster, De Kalb, Hermon, Edwards, Canton, Russell, Potsdam, Pierrepont, and Parishville; together with points reëxamined in the towns of Gouverneur, Rossie, and Fowler, which were covered in the examination made during 1893. The crystalline limestones, for which, in a previous report, the name Oswegatchie series was suggested, form belts stretching in a northeast-southwest direction. Four belts comprise a large proportion of the crystalline limestones of the region examined. The largest, the Gouverneur belt, extends from Antwerp to probably two miles south of Canton village. Northwest of this belt another belt extends from Theresa, across Rossie and Macomb, into De Peyster. This belt is perhaps separated from the first belt by narrow strips of gneiss, along the northern boundary of Gouverneur, although the precise extent of the gneiss belts is undetermined. The third belt, the Edwards belt, to the south of the Gouverneur belt, and separated from it by a belt of gneiss, begins in Fowler, crosses Edwards, and runs out in the western part of Russell. The fourth belt, the Diana belt, south of the Edwards belt, and separated from it by gneiss, crosses the towns of Pitcairn and Diana. In general, the limestones have their greatest development in the northwestern part of the region, decreasing as the eastern and southern parts of the district are approached.

The limestone is everywhere thoroughly crystalline, ranges in color from white to dark bluish-gray, and often contains disseminated and aggregated silicates, of which the more important are serpentine and tremolite.

The term gneiss is used to include rocks ranging from acidic to basic, from fine to coarse grained, and from distinctly gneissoid, or even schistose, to entirely massive. They constitute a complex series,

[1] Continued from page 205, Vol. VII., JOUR. GEOL.

[2] Report on the crystalline rocks of St. Lawrence county, by C. H. SMYTH, JR.: From the Fifteenth Ann. Rept. State Geologist, in Ann. Rept. of N. Y. State Museum, 1895, pp. 481-497.

f rocks, differing somewhat in age, and largely, if not almost wholly, f igneous origin. Parts of this series are clearly younger than the mestones; other parts may be older than the latter formation, ut there is nothing as yet to prove that such is the case. A robable exception to the latter statement is afforded by certain minated gneisses, of limited extent, which appear to underlie the mestone, perhaps marking the base of the series.

Many of the gneisses have heretofore been believed to be sedimen-ary, and the evidence leading to the conclusion that they are largely gneous may be briefly summarized: There is the negative evidence of the absence of all structures pointing to sedimentary origin; the niformity of composition and structure over wide areas, with changes by gradual transition; a common occurrence of massive cores, in every way identical with plutonic rocks; the presence of structures in the gneiss that would result from the application of pressure to igneous rocks; eruptive contacts between the abundant light-colored gneiss and the less common and older dark gneiss, together with widespread instances of inclusions of the dark gneiss in the light; the identity of the gneiss near Natural Bridge with the plutonic gabbro intrusive in the limestone; eruptive contacts at a number of places of the gneisses with the limestone.

Cushing[1] describes syenite-porphyry dikes in the northern Adirondacks. They are shown to be of pre-Cambrian age, but later than the gabbros and granites of the region. The syenite-porphyries constitute the complementary rocks to the diabases of the region, and ogether with them form an eruptive assemblage similar to that which haracterized Keweenawan time in the Lake Superior region.

Cushing[2] describes the geology of Clinton county, New York. he pre-Cambrian succession, following Kemp, is as follows: (1) a ısal gneissic series; (2) a series of schists and gneisses, with ystalline limestone; (3) igneous rocks of the gabbro type, intrusive the first two series. All of these are overlain unconformably by ıleozoic sediments. This classification is tentative, and probably npler than the one finally adopted is likely to be.

[1] Syenite-porphyry dikes in the northern Adirondacks, by P. H. CUSHING: Bull. S. A., Vol. IX, 1898, pp. 239-256.

[2] Report on the geology of Clinton county, by H. P. CUSHING: From the Fifteenth n. Rep. of the State Geologist, in Ann. Rep. of N. Y. State Museum, 1895, . 503-573.

1. The basic gneissic series appears in the western tier of townships of the county, with the exception of Clinton, Peru, and Ausable. The gneisses comprise several varieties, varying widely in texture and composition.

2. The series of schists and gneisses, with crystalline limestone, occurs only in Black Brook township. The limestone is coarsely crystalline, and much of it is quite pure, but very often it contains much green pyroxene.

3. The gabbros occur in three areas, which are outliers of the main gabbro massive of the Adirondacks. One is in Ausable township, extending north and west of Keeseville, and is the direct prolongation northeastward of a great gabbro ridge, which comes up to Keeseville from the southwest. The second forms Rand's Hill, in Beekmantown and Altona townships, twenty miles north of the first one. The third area forms the Catamount Mountain ridge, in southwestern Black Brook township.

After the intrusion of the gabbro, and prior to the Potsdam deposition, the region was subjected to intense metamorphism, resulting in the foliation and granulation of the rocks, with or without subsequent recrystallization.

Cushing[1] maps the boundary between the Potsdam and pre-Cambrian rocks north of the Adirondacks, from the line between Clinton and Franklin counties, west across Franklin county into St. Lawrence county, to a few miles west of Potsdam.

The sequence of rocks in the region is believed to be as follows:

1. A series of gneisses of great variety of structure and composition, in which all original structures are lost, of igneous origin. and in part at least of Archean age. They seem to grade into the basic gabbros of the region; at least the gabbros present phases not to be distinguished from the gneisses.

2. The Grenville series (Oswegatchie series) comprising quartzose gneisses and schists, quartz-feldspar-biotite gneisses, dioritic, and gabbroic gneisses, and occasional bands of coarsely crystalline limestone. These rocks are accompanied by belts of gneiss, similar to the older gneiss, which seem to be interstratified with the other rocks of this series, but whose relationships are doubtful. The gneiss of the Grenville series

[1] Report on the boundary between Potsdam and pre-Cambrian rocks north of the Adirondacks, by H. P. Cushing: Sixteenth Ann. Rep. N. Y. State Museum, 1898, pp. 1-27. With sketch map.

iffers in appearance from the older gneiss, and a considerable portion ͽems to be unquestionably of sedimentary origin, although dynamic ıetamorphism has obscured all traces of clastic structure and given ıe gneiss a foliation in common with the older gneisses, rendering ıe field relations obscure. From Parishville westward to Potsdam the ;renville series is more widely distributed, less faulted, and less ompletely metamorphosed, and hence with its sedimentary character ess disguised, than the Grenville series farther east, probably because ıf its greater distance from the anorthosite intrusion. However, it eems to be beyond question that the eastern and western series are quivalent.

3. The anorthosite intrusion.
4. Later gabbros.
5. Granitic intrusions. The region was then subjected to intense lynamic metamorphism, after which occurred the intrusion of
6. Diabase and trachyte dikes.
7. Paleozoic rocks overlying unconformably all the preceding.

Kemp[1] continues his preliminary report on the geology of Essex county, N. Y., with an account of the detail geology of the individual townships. The additional observations have corroborated the conclusions reached in his previous report on this county,[2] concerning the main classification of the rocks of the area, although it is now doubtful if a sharp stratigraphic distinction can be drawn between Series (1) and (2).

Kemp[3] describes and maps the geology of the Lake Placid region in the Adirondacks of the northwest part of Essex county. Crystalline rocks of Algonkian age occupy a large part of the area. These include crystalline limestone, quartzite, granite, gneiss, and anorthosite. It is probable that some of the gneisses, and especially those associated with the limestones and quartzites, are altered sediments, and it is also probable that the gneisses with augen of labradorite are squeezed igneous rocks, but the investigation does not permit of their

[1] Preliminary report on the geology of Essex county, by J. F. KEMP: From the Fifteenth Ann. Rep. of the State Geologist, in Ann. Rep. of N. Y. State Museum, 1895, pp. 579-614. With geol. maps.

[2] See Report of State Geologist of New York for 1893, pp. 433-572. Summarized ı Journal of Geology, Vol. VI., 1898, pp. 528-529.

[3] Geology of the Lake Placid region, by J. F. KEMP: Bull. N. Y. State Museum, ol. IV., 1898, pp. 51-64. With geol. map.

separation. The anorthosites have intruded and metamorphosed the limestones and quartzites, and probably some of the gneisses. It has been noted that the anorthosite frequently passes outward by gradual transition into the dark gneisses with labradorite augen. Cutting all the above rocks are trap dikes, but whether pre-Cambrian or later, is unknown.

GENERAL COMMENT ON THE ADIRONDACK WORK

The above conclusions are of much interest as bearing on the general problems of the origin and age of the gneisses associated with the limestones of the Adirondack region. Kemp,[1] working on the eastern side of the district, has previously concluded that it does not appear certain that in the eastern Adirondack region there are any rocks older than the clastic series. As a result of field work on the eastern and western sides of the district, Van Hise[2] has held that most of the gneisses are clastic, but that a part of the red gneisses may be older than the clastic series, and therefore of Archean age. From the above summaries it appears that Kemp in his recent work still maintains the absence of the Archean. Cushing, working mainly in the northern part of the region, although overlapping Smyth's area a little way on the west, places in a lower series gneisses which he believes to be in part at least of Archean age, holds that a considerable portion of the gneisses associated with the limestones are unquestionably of sedimentary origin, and offers no evidence to show that any of the gneisses associated with the limestones are igneous and later than the limestone. Smyth, working entirely on the western side of the region, concludes that the presence of the Archean or basement gneiss has not been shown; that certain of the gneisses associated with the limestones may be sedimentary; but that the greater part of the gneisses of the district are igneous and later than the limestone. He thus agrees with Kemp on the point of the absence of the Archean.

It is to be remembered that Kemp, Cushing, and Smyth have been working in different areas. Each of them may be right as to the origin of the gneisses of his area and there may be present in the Adirondack district Archean, Algonkian, and post-Algonkian gneisses. Such is approximately the case in the Lake Superior region,

[1] Bull. G. S. A., Vol. VI., 1895, p. 251.

[2] Bull. 86 U. S. Geol. Survey, 1892, pp. 413-414, and sixteenth Ann. Rep. U. S. Geol. Survey, 1896, pp. 771-773.

where we have Archean and Algonkian gneisses and post-Algonkian granites.

While in different parts of the region the different conclusions above outlined have been reached, for the Adirondack region as a whole this much seems to have been shown. There is present a series of completely crystalline limestones and graphitic quartz-schists of sedimentary origin and pre-Cambrian age; closely associated with these are beds of graphitic and other gneisses, which are also sedimentary; cutting all the sedimentary rocks are gneisses of igneous origin, certain granites, and the great gabbro mass. That there is present a basal gneiss, while probable, has not been demonstrated. The question is still open. For much the larger part of the region also there remains for future work the discrimination of the sedimentary gneisses and the igneous gneisses of later origin.

The lithological similarity of the Adirondack sedimentary series with the Grenville series of the Original Laurentian district to the north has frequently been commented upon. In the latter district it has been possible lately to separate the sedimentary gneisses associated with the limestones from the true igneous gneisses of the Basement Complex by means of chemical analyses. The success of this method in the Original Laurentian district suggests that it may afford the best means for a satisfactory determination of the origin of the lower gneisses in the Adirondack district.

Miller[1] describes the occurrence of corundum in gneiss, syenite, and quartz-pegmatite of the Laurentian in the counties of Hastings, Renfrew, and Peterborough, in eastern Ontario.

Adams[2] reports on the geology of a portion of the Laurentian area lying to the north of the island of Montreal.

A previous report[3] summarized in this JOURNAL (Vol. VI., pp. 850-852), covers about the southeastern quarter of this area, and in a general way the conclusions reached for this southeastern area are applied to the larger area under discussion.

[1] Economic geology of eastern Ontario, corundum and other minerals, by WILLETT G. MILLER: Report of the Bureau of Mines, Ontario, Vol. VII., 1898, pp. 207-238.

[2] Report on the geology of a portion of the Laurentian area lying to the north of the island of Montreal, by FRANK D. ADAMS: Ann. Rep. Geol. Surv. of Canada, Vol. VIII., 1897, part J, pp. 184. With geological map.

[3] Ann. Rep. Geol. Surv. of Canada for 1894, Vol. VII., 1896, part J.

The Archean geology is summarized by the author as follows:

1. The Archean rocks in this area are of Laurentian age,[1] and are in part referable to the Grenville Series and in part to the Fundamental Gneiss.

2. The Grenville Series contains gneisses, as well as limestones and quartzites, which are of aqueous origin, having the chemical composition and the stratigraphical attitude of sedimentary rocks. With these are intimately associated, however, other gneisses which are of igneous origin.

3. The Fundamental Gneiss consists largely, if not exclusively, of igneous rocks in which a banding or foliation has been induced by movements caused by pressure.

4. Both series are penetrated by various igneous masses, of which the most important are great intrusions of anorthosite, a rock of the gabbro family, characterized by a great preponderance of plagioclase. This rock is in places perfectly massive, but generally exhibits the irregular structure which is so often observed in gabbros and which is brought about by a variation in the size of the grain or the relative proportion of the constituents from place to place. In addition to this original structure, the rock almost always shows a peculiar protoclastic, cataclastic or granulated structure which is especially well seen in the foliated varieties. This differs from the structure characteristic of dynamic metamorphism in the great mountainous districts of the world, having been produced by movements in the rock-mass while this was still deeply buried in the crust of the earth and probably very hot perhaps near the melting point.

5. The same granulated structure is also seen in all those gneisses which have been formed from massive igneous rocks by dynamic movements.

6. The fine grained aqueous rocks of the Laurentian, on the other hand, have been altered chiefly by a process of recrystallization.

7. The "Upper Laurentian" or "Anorthosite Group" of Sir William Logan does not exist as an independent geological series—the anorthosite, which was considered to be its principal constituent, being an intrusive rock, and its remaining members belonging to the Grenville Series.

8. In all cases of supposed unconformable superposition of the

[1] In the sense of pre-Cambrian or Original Laurentian.

anorthosite upon the Laurentian gneisses, which have been carefully investigated, the unconformability is found to be due to intrusion.

9. The anorthosites are probably of pre-Cambrian age, and seem to have been intruded about the close of the Laurentian.

10. The Canadian anorthosites are identical in character with the anorthosites associated with the Archean rocks of the United States, Norway, Russia, and Egypt. The Norwegian occurrences, however, are probably more recent in age than those of Canada.

Adams and Barlow[1] give a general outline of geological work begun, but not yet finished, in the Laurentian of central Ontario, in the area comprising map sheets No. 118 and a portion of 119 of the Ontario series of geological maps, and indicate certain conclusions which seem likely to be reached concerning the origin and relations of the Grenville and Hastings series.

The Fundamental Gneiss occupies the northwestern, and by far the larger portion of the area. It consists of igneous rocks closely allied to granites, diorites, and gabbros, all showing more or less distinct foliation.

The Grenville and Hastings series are principally exposed in the southeastern portion of the area, the Grenville series appearing in a belt adjacent to the Fundamental Gneiss, and between the Fundamental Gneiss and the Hastings series.

The Grenville series is composed principally of gneisses identical in character with the Fundamental Gneiss, but it contains also, and is characterized by a small quantity of altered sediments, chiefly limestone. Some varieties of the gneissic rocks may owe their origin to the partial commingling of the sedimentary material with the igneous rocks by actual fusion. The strike of the foliation of the rocks of the series follows in a general way that of the Fundamental Gneiss. The Grenville series is believed to be a sedimentary series, later than the Fundamental Gneiss, which has sunk down into, and been invaded by, intrusions of the latter series when this was in a semi-molten or plastic condition.

The Hastings series is composed chiefly of thinly bedded limestones, dolomites, etc., cut through by great intrusions of gabbro, diorite, and granite. This series is believed to represent the Grenville

[1] On the origin and relations of the Grenville and Hastings series in the Canadian Laurentian, by F. D. ADAMS, and ALFRED E. BARLOW: Am. Journ. Sci., 4th ser., Vol. III, 1897, pp. 173-180.

series in a less altered form. That is, the Fundamental Gneiss, upon which the Hastings series was originally laid down, having at a subsequent time been softened by the influence of heat, and having under the influence of dynamic action eaten into and fretted away the overlying Hastings series, gave rise to an intermediate zone of mixed rocks which constitutes the Grenville series. The Grenville series may, however, represent only a portion of the Hastings series, and the work so far done has been insufficient to determine the stratigraphical position of this portion. It seems probable that the age of the Hastings series will be shown to be Huronian.

The Grenville and Hastings series are unconformably overlain by, and disappear to the south beneath, flat-lying Cambro-Silurian rocks.

Ells[1] gives a general account of the Archean of eastern Canada, including a review of the various classifications made by the earlier geologists, and their recent modifications. It is concluded that it is possible to reduce the great series of the so-called Laurentian rocks to two principal divisions, viz., a lower Basal or Fundamental Gneiss, in which all traces of sedimentation are wanting, and which may be regarded as representing in altered form some portion of the original crust of the earth; and a newer, secondary series, derived doubtless from the decay of the former, in which the evidences of clastic origin are manifest. On this basis the arrangement of the systems for eastern Canada would be as follows:

LAURENTIAN, NON-SEDIMENTARY

Basal or Fundamental Gneiss (Ottawa gneiss), representing in altered form the original crust of the earth, and the lowest known series of rocks; without evidence of sedimentary origin.

HURONIAN, PARTLY SEDIMENTARY AND PARTLY IGNEOUS

Grenville and Hastings series, comprising limestones, quartzites, gneisses, etc., of Ontario and Quebec, in the Ottawa district.

Schists and altered slates, chloritic and other crystalline rocks of the Eastern Townships of Quebec, and the Gaspé peninsula.

Felsitic and gneissic rocks of northern New Brunswick.

Gneiss, quartzite, and limestone, of the so-called Laurentian of southern New Brunswick, regarded as the equivalents of the Grenville

[1] Notes on the Archean of eastern Canada, by R. W. ELLS: Proc. and Trans Royal Society of Canada, 2d series, Vol. III, 1897, Sec. 4, pp. 117-124.

and Hastings series, felsites and schistose rocks of the Coldbrook, Kingston and Coastal divisions, the apparent equivalents of the rocks of the Sutton Mountain anticlinal.

Felsitic and syenite rocks of eastern Nova Scotia and northern Cape Breton, with their associated crystalline limestones and serpentines.

CAMBRIAN

Cambrian slates, sandstones, and conglomerates.

General comment.—The succession and correlation proposed in the above papers by Adams and Barlow and by Ells are fundamentally different from the traditional one which has been held in Canada for many years. The first departure is in placing the Grenville and Hastings series as equivalent to the Huronian. Ells goes further and places with the Huronian all the sedimentary rocks of eastern Canada. This usage of the term Huronian restricts the Laurentian to the basal or fundamental gneiss. While the names are different, this is essentially the classification proposed by Van Hise in his Correlation Paper —Archean and Algonkian, in 1892. However, in place of Laurentian, he would use the term Archean. Also he would restrict the term Huronian to the rocks of the Original Huronian area and their equivalents. As it is impossible to be certain whether or not sedimentary series of eastern Canada not structurally connected with the Original Huronian are really equivalent to it, he has included the rocks above called Huronian under another name—Algonkian, a broader term covering all pre-Cambrian sedimentaries and contemporaneous eruptives, including the Keweenawan. The essential point, the existence of a non-sedimentary basal complex separated by a profound unconformity from a later pre-Cambrian series, partly sedimentary and partly igneous, is agreed upon.

Willmot[1] describes the geology of the Michipicoton mining division, which is limited on its eastern side by the 84th meridian, on the west by Lake Superior, on the south by latitude 47° 30′, on the north by latitude 48° 30′. Most of the rocks of the area belongs to the Laurentian and Huronian. The northern, eastern, and southeastern portions of the area are occupied by the Laurentian; the central and southwestern portions by the Huronian. The Laurentian is almost everywhere a fine

[1] The Michipicoton mining division by A. B. Willmot: Report of the Bureau of Mines, Ontario, Vol. VII, 1898, pp. 184–206.

grained gray gneiss, which often becomes granitic and coarser grained in texture. The Huronian rocks are most commonly massive diorites and diabases, and hornblende and chlorite-schists; less commonly, they are slates, felsites, quartzites, and sericite-slates. The Laurentian is frequently in eruptive contact with the Huronian.

In two areas, the Nipigon or Keweenawan rocks overlie the Huronian and Laurentian rocks. These areas are one two miles north of Cape Choyye and one on the peninsula of Gargantua.

Walker,[1] in 1897, describes the stratigraphy and petrology of the Sudbury nickel district of Canada. The oldest rocks of the district are gneisses of various kinds, which are regarded as of Laurentian age. Next in age to the gneisses is a belt of rocks consisting of quartzite, graywacke, amphibolite, mica-schist, phyllite, clay-slate, and altered volcanic breccia, which extends from the north shore of Lake Huron northeastward to Lake Mistassini, in the neighborhood of Sudbury, the belt being about twenty-five miles wide. The rocks of this belt are believed to be of Huronian age. The Huronian rocks have suffered severe metamorphism, and the original character of many of them cannot be made out. In and adjoining the Huronian belt are elliptical areas of later eruptive greenstone, in places intimately associated with and genetically inseparable from gneissoid and micropegmatitic granites. The nickel ore, principally pyrrhotite, occurs intimately intermingled with the eruptives, and is regarded as a concentration by differentiation from the eruptive magma. Cutting both the Huronian and the included nickel-bearing eruptives are masses of fine grained pinkish biotite-granite, sending apophyses into the surrounding rocks. This granite is found to have been intruded in two eruptions. The youngest rocks of the Sudbury district are olivine-diabases, which occur in dikes, cutting all the other rocks of the district.

Bell[2] reports on the geology of the French river sheet, which represents the country around the north end of Georgian Bay. Huronian rocks occupy the northwest corner of the sheet, and Laurentian rocks all the area to the southeast.

[1] Geological and petrographical studies of the Sudbury nickel district of Canada, by T. L. Walker, Q. J. G. S., Vol. LIII, 1897, pp. 40–66. With geol. map.

[2] Report on the geology of the French river sheet, Ontario, by Robert Bell: Ann. Report of the Geol. Surv. of Canada for 1896, Vol. IX, 1898, Part 1, pp. 29. With geol. map.

The Laurentian rocks in general resemble the Grenville series, nich belong to the upper division of the Laurentian. They consist of d and gray mica and hornblende-gneisses in beds which can be aced with regularity for considerable distances, together with coarse ornblende and mica-schists and bands of quartz-rock with schistose artings. No limestones have yet been found among those rocks ithin the boundaries of the sheet, but in the Parry Sound district to ie eastward, among similar strata, the writer has traced five bands of ystalline limestone like those of the Grenville series. The gneisses re distinctively stratified and regularly arranged in anticlinal and ynclinal forms, according to the structural laws governing stratified ocks; the average angles of dip are not steep, and in general, so far s their texture is concerned, the gneisses have the characters of ltered sedimentary deposits. Cutting the granites are greenstone ikes, with an east and west direction.

The Laurentian rocks northwest of the Huronian area, outside of he area of the sheet, are considered to belong to the older division of he system.

The Huronian rocks comprise quartzites, sericite-, chlorite , horn-blende-, and arkose-schists, clay-slates, graywackes, and dolomites. They have a general synclinal structure. The quartzites of the ridges north-west of Killarney form the southern side of the basin, and those of he Cloche mountains the northern side. Along the southern side of he major syncline are several subordinate folds. Associated green-stones are less conspicuous than in the Huronian rocks on the Sudbury sheet to the north. Those present are more largely developed in the ract on the south side of Lake Panache than elsewhere.

In the space between the Cloche mountains and the range which uns eastward from McGregor Point to Sturgeon Lake, including Bay f Is'ands, McGregor Bay, and the land thence eastward to the junc-on of the two chains, the rocks belong to a local division of the [uronian which may, for present convenience, be called the arkose eries, with its associated rocks. Structurally this area would appear o occupy the central part of the synclinal area between the above-entioned conspicuous quartzite ranges. Although various forms of kose or graywacke are the prevailing rocks within this space, there e in different parts of it considerable quantities of gray quartzites and ie quartz-conglomerates, mixed agglomerates and breccias, sericitic id micaceous schists, impure dolomites and eruptive greenstones.

As to the origin of these rocks, the thick unstratified and brecciated graywacke or arkose may represent consolidated masses of volcanic ashes or mud with stones, which were thrown upon the land or into shallow water, while the stratified varieties may have consisted of similar ejectamenta, thrown into deeper water where they became arranged into layers as we find them. Some of these rocks, whether stratified or otherwise, may represent volcanic products which were originally thrown into the sea in a molten or heated condition and became broken up and almost completely disintegrated.

A study of the different phases of the graywackes and their associated rocks in this region would appear to prove that the former constituted the crude material from which both the quartzites and clay-slates were derived by the modifying and separating action of water. Again, by the action of time, pressure, heat, and other metamorphosing agents upon different varieties of graywacke, some of our granites, syenites, gneisses, and possibly other crystalline rocks, were probably formed.

Solid and slaty argyllites are found along Long Lake, an expansion of the Whitefish River, and slate conglomerates occur on both sides of Bear Lake and between Cat and Leech lakes. However, these rocks do not form a large proportion of the Huronian series in this district.

Impure magnesian limestones occur in the northern part of the Bay of Islands, in the northwest part of the township of Rutherford, and north of the area of the sheet near Lake Panache.

Between the Huronian rocks on the north and the Laurentian rocks on the southeast there is a belt of red granite, the Killarney belt, running from Badgely Island to Three-mile Lake. This granite is apparently of eruptive origin, and of later age than the quartzites. All along the line of contact with the Huronian the rocks give evidence of great disturbance. Huge portions, as well as many of moderate size, have been separated from both sides and have been mingled together and intermixed with finer débris, all being cemented into a coarse breccia.

The southeastern side of the Killarney belt of granite rests against the Laurentian gneiss, except in the interval from the southern point of George Island to the entrance of Collins Inlet, where a narrow belt of partially altered, fine grained, brittle, red and sometimes gray quartzite intervenes between the granite and the water of Georgian Bay. Further northeastward, or where the granite of the Killarney

belt comes into contact with the gneiss which prevails to the eastward, it is not always separated from the latter by a very distinct boundary. The rocks in some places pass into each other more or less gradually.

Barlow and Ferrier[1] discuss the relations and the structure of certain granites and associated arkoses on Lake Temiscaming. An examination of the contact of the granite and arkose shows a gradual and distinct passage of the granite into the arkose. Microscopically also there may be seen evidence of the decomposition of the feldspars of the granite, the breaking up of the feldspar and quartz, and finally the rearrangement and assortment of by water, indicating a gradual transition from the granite to the arkose.

The arkose is regarded as an Huronian sediment derived from and deposited on the granite. This is regarded as the only instance at present known in which the material composing the Huronian clastics can be clearly and directly traced both macroscopically and microscopically, to the original source from which it has been derived.

Comment.—The final statement is somewhat sweeping. Passing over the numerous instances of clear relations south of Lake Superior, it is necessary only to recall the instances close at hand, at Thessalon and Garden River, described by Irving, Pumpelly, and Van Hise, who found complete evidence of the unconformable relation between the Laurentian and Huronian, and of the derivation of the Huronian sediments from the Laurentian.

Burwash,[2] during the survey of the boundary line between the districts of Nipissing and Algoma in Canada, takes geological notes of the area traversed.

The run was made from south to north, from the upper waters of the Vermilion and Wahnipitae rivers, to within thirty-five miles of Lake Abittibi; and, with the exception of two areas of eruptive granite, the country was found to be underlain for the entire distance by Huronian rocks. The section is given in detail.

Tyrrell and Dowling[3] report on the country between Athabasca

[1] On the relations and structure of certain granites and associated arkoses on Lake Temiscaming, Canada, by A. E. BARLOW and W. F. FERRIER: Geol. Mag., Vol. V, 1898, pp. 39–41.

[2] Geology of the Nipissing-Algoma line, by EDWARD M. BURWASH: Sixth Rep. of the Bureau of Mines, Ontario, 1897, pp. 167–184.

[3] Report on the country between Athabasca Lake and the Churchill River in Canada, by J. B. TYRRELL, assisted by D. B. DOWLING: Ann. Rep. Geol. Surv. of Canada, Vol. VIII, 1897, Part D, pp. 120 with geol. map.

Lake and the Churchill River in Canada. The area covered by the report is bounded on the south by the Churchill and Clearwater rivers; on the west by the lower portion of the Athabasca River; on the north by Athabasca Lake, Stone River, with its expansions, Black and Hatchet lakes, Wollaston Lake, and Cochrane or Ice River; on the east by the lower part of the Cochrane River, Reindeer Lake, and Reindeer River.

Laurentian rocks, including hornblende-granites, biotite granites, muscovite granites, granitoid gneisses, gabbros, and norites, are found outcropping on the Churchill River from two miles below the mouth of the Mudjatick River eastward to the mouth of the Reindeer River; thence northward they occupy most of the eastern part of the district. Further west they are followed north to Cree Lake. In the northern part of the area they occupy most of the northern shores of Athabasca and Black lakes.

As far as at present known, the Huronian is represented in this district solely by three small areas on the north shore of Lake Athabasca. The Huronian here includes quartzites, calcareous sandstones and schists, conglomerate, hälleflinta, ferruginous chlorite-schists, and other green schists.

The Laurentian and Huronian are unconformably overlain by horizontal sandstones and conglomerates, called the Athabasca sandstone, which is placed in the Cambrian. However, these sandstones are similar to the sandstones found to the north associated with quartz-porphyries, diabases, etc., like those of the Keweenawan of Lake Superior, and there is little doubt that the two sets of rocks belong to the same horizon.

Tyrrell[1] reports on an exploration of the Doobaunt, Kazan, and Ferguson rivers northwest of Hudson Bay, the northwest coast of Hudson Bay, and on two overland routes from Hudson Bay to Lake Winnipeg.

Laurentian rocks, including granites, diorites, and granite and diorite gneisses, occupy a large part of the region crossed by the three main lines of travel — the Doobaunt River and Chesterfield Inlet, the Kazan and Ferguson rivers, and the west coast of Hudson Bay,— although their precise extent is unknown.

The Huronian rocks include three more or less distinct groups, the Marble Island quartzites, the greenish quartzites and graywackes, and

[1] Report on the Doobaunt, Kazan, and Ferguson rivers, and on the northwest coast of Hudson Bay, by J. B. TYRRELL: Ann. Rep. Geol. Surv. of Canada, Vol. IX, 1898, Part F, pp. 218. With geol. maps.

he more or less highly altered and often schistose diabases and gabbros. The largest area of Huronian is found along the coast of Hudson Bay from Baker's Foreland south to a point forty-five miles north of Cape Esquimaux, and inland for seventy miles up the Ferguson River. Other areas are found between Schultz and Baker lakes, near Lake Angikuni, near Kasba and Ennaidai lakes, the north shore of Doobaunt Lake, and the east shore of Wharton Lake.

The Huronian rocks are overlain unconformably by the Athabasca sandstone. As this sandstone is older than the flat-lying Cambro-Silurian limestone, and unconformably above the Huronian, it is assigned to the Cambrian, although no fossils were found in the formation. Lithologically the whole terrane presents a remarkable resemblance to the red sandstones and Cambrian quartz porphyries of the Keweenawan rocks of Lake Superior, and the two terranes are regarded as holding essentially similar positions in the geological time scale.

Low[1] reports on his explorations of the Labrador Peninsula, along the East Main, Koksoak, Hamilton, Manicuagan, and portions of other rivers. Laurentian rocks occupy nine tenths of the area of the Peninsula. They include gneisses and schists, some of clastic origin, some of eruptive origin. The clastic portion is in nearly all cases the oldest.

The Huronian rocks comprise beds of arkose, conglomerate, limestone, shale, slate, sandstone, chert, quartzite, mica-schist, and eruptives, in part at least contemporaneous with, and at present represented by, schists characterized by chlorite, epidote, altered hornblende, hornblende, sericite, and hydromica; also diabases, diorites, and various granites. They occur in two large areas and several small ones. The large areas are along the East Main River from near the mouth inland for 160 miles, and the area of the large lakes southwest of Lake Mistassini.

The Laurentian and Huronian rocks are overlain with strong unconformity by a series of rocks classified as Cambrian, comprising arkose, sandstone, limestone, dolomite, felsitic shale, argillite, and argillaceous shale, together with gabbro, diabase, fine grained, decomposed traps,

[1] Report on explorations in the Labrador Peninsula, along the East Main, Koksoak, Hamilton, Manicuagan, and portions of other rivers, in 1892, 1893, 1894, and 1895, by A. P. Low: Ann. Rep. Geol. Surv. of Canada, Vol. VIII, 1897, Part L, pp. 387. With geol. maps.

and volcanic agglomerates. The fine grained traps are interbedded with the clastic rock. No acid eruptives appear. On the east coast of Hudson Bay and at Chateau Bay near the eastern entrance of the Strait of Belle Isle, some of the traps have formed overflows on the surface, and are now represented by dark green, fine-grained melaphyres having large amygdaloidal cavities filled with quartz and agate. No fossils have been found in these supposed Cambrian rocks and their precise age and equivalency can only be conjectured. However, the mode of occurrence of thick beds of magnetic iron ore overlain by cherty, nonfragmental carbonates in this series, closely resembles that of the iron ores of the Lake Superior region described by Irving, Van Hise, and others. This, with other characters of resemblance, renders it almost certain that the two developments represent the same period, or, in other words, that the Animikie rocks of Lake Superior, assumed to be Lower Cambrian, are equivalent to the rocks here described as Cambrian in Labrador.

Low[1] reports on a traverse of the northern part of the Labrador peninsula, from Richmond Gulf to Ungava Bay. Laurentian rocks occupy the greater part of the area. These are chiefly granites, more or less foliated. They are of different ages, but, except in a few cases, they cannot be discriminated. Cutting them are intrusive diabases.

Intimately associated with the granites is a series of more or less quartzose mica-gneisses and mica-schists, interbanded with hornblende-schists and hornblende-gneisses; and at times with quartz-magnetite gneiss. These gneisses and schists are supposed to represent a bedded series of rocks somewhat similar to the Grenville series. While most of the schists are thus probably very ancient, others may be of the same age as the Cambrian.

Cambrian rocks were met with along the east coast of Hudson Bay, to the northward of Cape Johns, and on the Larch River from its junction with the Kaniapiskau upwards for thirty miles. A section examined on the east side of Castle peninsula, on the north side of the outlet of Richmond Gulf, presents rocks closely resembling the Mesnard quartzites and the Kona dolomites of the Lower Marquette series of the south shore of Lake Superior, capped by a later outflow of trap, classed as Algonkian by Van Hise.

[1] Report on a traverse of the northern part of the Labrador peninsula, from Richmond Gulf to Ungava Bay, by A. P. Low: Ann. Rep. Geol. Surv. of Canada for 1896, Vol. IX, 1898, Part L, pp. 1-43. With geol. map.

Comments.—In the explorations by Tyrrell and Low, considering the time available and the ground covered, the determination of the geological series was necessarily of the most hasty nature. Nothing but the roughest petrographical discriminations could be made, and no structural work was possible. Their terms Laurentian, Huronian, and even Cambrian, therefore, indicate only the broad petrographical features of the rocks traversed, and do not stand for well defined series equivalent to the series so named to the south.

Following the usage of many of the Canadian geologists, the Cambrian is made to include rocks supposedly equivalent to the Cambrian, Keweenawan, and Animikie of the Lake Superior region, and Low carries it down even to include formations similar to Lower Marquette formations of the Lake Superior country. In the Lake Superior region, where most thoroughly studied, the Keweenawan and Huronian formations are separated from each other and from the Cambrian by well marked unconformities, unconformities uniformly recognized by geologists who have done close work in this region. These unconformities have been recognized also in other parts of North America. If the rocks above called Cambrian are really equivalent to the various Lake Superior series mentioned, then the extension downward of the Cambrian, across well established unconformities, to include such series, has no reasonable basis. However, in view of the scanty observations and the absence of connecting structural work, any correlation at present is little more than a suggestion, and for this reason it would be better to give the formations local names, as was done by Tyrrell in the case of the Athabasca sandstone. Thus would be avoided the confusion arising from the misuse of well defined and well established terms like Cambrian, Keweenawan, and Huronian.

Bailey[1] reports on the geology of southwest Nova Scotia. Cambrian rocks devoid of fossils occupy a large part of the area. The succession is, in ascending order, as follows:

I. Quartzite Division.
  - (*a*) Heavily bedded bluish quartzites, alternating with much thinner beds of argillite.
  - (*b*) Greenish-gray sandstones or quartzites, somewhat chloritic and less massive than in (*a*), and alternating with slates which are arenaceous below but become progressively more argillaceous above.

[1] Report on the geology of southwest Nova Scotia, by L. W. BAILEY: Ann. Rep. Geol. Surv. of Canada, Vol. IX, 1898, part M, p. 154. With geol. map.

II. Banded Argillite Division.

(a) Greenish-gray slates, becoming bluish or light gray, and passing upwards into

(b) Purple slates, marked in the lower beds by pale, yellowish-green seams, with faint bedding lines, which are wanting in the higher beds.

(c) Bluish-gray and gray slates, often with cloudings of green, purple, lilac, buff, or yellow, in places exhibiting a conspicuous banding or ribboning of the beds.

III. Black Slate Division.

Black, with some blue or gray slates, often studded with cubes of pyrites, and very rusty-weathering.

Comment.—Here again the Cambrian has been extended downward to cover rocks, devoid of fossils, which have been mapped as Algonkian by Van Hise.[1]

Dawson[2] presents a brief note on Cryptozoon and Archæozoon found in the pre-Cambrian. A general discussion is given of the biological affinities of the Cryptozoon and Archæozoon, and descriptions are quoted of younger forms which may be the successors of the pre-Cambrian forms.

Dawson,[3] in an account of the physical geography and geology of Canada, sketches the distribution and characters of the pre Cambrian rocks.

Dawson[4] gives a general account of the pre-Cambrian rocks of Canada. This is largely a discussion of pre-Cambrian classification and nomenclature, based on a review of early and recent work on the pre-Cambrian of Canada, and will, therefore, not be fully summarized. A few of the more important conclusions may, however, be mentioned.

The Laurentian still includes both Fundamental Gneiss and the Grenville series.

[1] Bulletin 86, U. S. Geol. Survey, Pl. V. Sixteenth Ann. Rept., Pl. CVIII.

[2] Note on Cryptozoon and other ancient fossils, by SIR WILLIAM DAWSON: Canadian Record of Sci., Vol. III, pp. 203–219.

[3] The physical geography and geology of Canada, by G. M. DAWSON: Handbook of Canada, issued by the Publishing Committee of the Local Executive of the British Assoc., Toronto. 1897.

This is largely a general summary of the present state of knowledge concerning the geology of Canada, and will therefore not be fully reviewed.

[4] Presidential address to the geological section of the British Association for the Advancement of Science, by G. M. DAWSON: Proc. Brit. Assoc. Adv. Science for 1897, Section C, p. 13

The Huronian proper, under whatever local name it may be classed, still remains a readily separable series of rocks.

The Upper Laurentian, Labradorian, Norian, or anorthosite group is found to consist essentially of intrusive rocks, later in age than the Grenville, but in all probability pre-Paleozoic.

The general tendency in our advance in knowledge appears to be in the direction of extending the range of the Paleozoic downward, whether under the old name of Cambrian, or under some other name, applied to a new system defined, or likely to be defined, by a characteristic fauna; and under Cambrian, or such new system, if it be admitted, it is altogether probable that the Animikie and Keweenawan rocks must eventually be included.

The introduction of the term Algonkian, proposed to include the recognizable sedimentary formations below the Olenellus zone, and their igneous equivalents, is believed to be a backward step, for the following reasons: It detaches from the Paleozoic great masses of conformable and fossiliferous strata beneath an arbitrary plane and unites these under a common systematic name with other vast series of rocks, now generally in a crystalline condition; it includes as a mere interlude, what, in the region of the Protaxis, is one of the greatest gaps known to geological history; and it does not in the least degree remove the difficulty found in defining the base of the Grenville series.

Comment.—The statements that there is a general tendency to extend the term Paleozoic downward as our knowledge advances, and that the introduction of the term Algonkian is a backward step, would not be agreed to by the United States geologists. However, this subject is too complex to be discussed in the space at our disposal. Those interested are referred to Bulletin 86 of the U. S. Geol. Survey, and to the Principles of North American pre-Cambrian Geology in the Seventeenth Annual Report of the U. S. Geol. Survey.

MADISON, WIS. C. K. LEITH.

REVIEWS

West Virginia Geological Survey. Vol. I. By I. C. WHITE, State Geologist.

The Geological Survey of West Virginia was established, with a small appropriation, by an enactment of the legislature of that state passed in February, 1897. Dr. I. C. White was appointed state geologist and he entered upon the active duties of his office January 1, 1898. The present volume is the first publication of the survey and in it is incorporated a part of the results of investigations prosecuted during 1898.

The report is a paper covered octavo volume of 392 pages and consists of four parts. Part I (pp. 1–26) is a "Report of the State Geological Commission to the Legislature, containing an account of the operations of the survey during the years 1897 and 1898." Part II (pp. 27–53) is entitled "Levels above Tide." It is a compilation of the elevations of the several stations on all the principal railroads of the state, the data for which were contributed by the officers of the roads.

Part III (pp. 54–122) upon the "Variation of the Magnetic Compass" and "True Meridian Lines in the Several Counties of the State" was prepared by R. U. Goode, Geographer, United States Geological Survey in coöperation with the state survey. Meridian monuments were placed in the county seats of each county in the state, and detailed descriptions of the location of the monuments are given in this paper.

The major part of the volume (Part IV, pp. 123–378) is devoted to a report on "Petroleum and Natural Gas" by the state geologist. The report is opened with a historical sketch which is followed by an account of the geology of petroleum and natural gas. A large amount of information which will be of great value to the oil and gas industry of the state is here published.

It is unfortunate that the volume should contain no index, but, as stated by the state geologist, it had to be omitted because of the

lack of sufficient funds. It is to be desired that the State of West Virginia may see fit to continue the work of their geological survey so well begun, by appropriating for it sufficient funds to carry out the work as outlined by the state geologist in Part I of this volume.

S. W.

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A NEW ANALCITE ROCK FROM LAKE SUPERIOR

AMONG other regions on the northern shores of Lake Superior examined last summer by the writer for the Ontario Bureau of Mines the vicinity of Heron Bay, where the Canadian Pacific Railway first touches the lake when coming from the east, proved very interesting, a thick series of schist conglomerates with pebbles and bowlders mainly of felsite and quartz-porphyry occurring there, mapped by Dr. Bell of the Canadian Geological Survey as Huronian. Along the rocky shore of the bay, and also in cuttings on the railway west of the station, good exposures of these rocks are seen, sometimes so rolled out that the forms of the pebbles are almost, or completely, lost. Crossing the schist conglomerates are numerous dikes, which unfortunately were not carefully studied owing to lack of time, though hand specimens of the more typical dike rocks were taken. In the field the dikes were considered to consist of diabase, diabase-porphyrite, and felsite, all common rocks in the western Keewatin.

Microscopical study of the specimens obtained showed that the diabase and porphyrite present no unusual features, and that one of the felsitic-looking rocks is quartzless porphyry of a kind common in western Ontario. Another rock taken for felsite, dark red and slightly spotted with green, turns out, however, to

be of a new type, and will be described here because of its interesting mineralogical and chemical composition.

The specimens were obtained near mile 804 in a cutting on the railway, one being chosen to represent the freshest material seen, another weathered, and presenting a mottling of red and dark green, almost suggesting a variety of amygdaloid. Sections of the latter specimen are so completely weathered that little of its original composition can be determined; but sections of the fresh specimen show that the greenish spots consist almost wholly of feldspars having a confused radiating arrangement giving spherical forms; while the red part is composed of an isotropic base like a clear glass penetrated by radiating bundles of green prisms and also larger bundles of feldspar laths, brown with particles of iron oxide. A little calcite scattered through the section proves that the rock is no longer fresh.

The vague spheres of feldspar often have an imperfect black cross in polarized light, and consist mainly of orthoclase, somewhat turbid and specked with brown iron oxide, with a little of the green mineral intermixed. The rest of the rock contains some orthoclase also, but consists chiefly of the isotropic substance inclosing the radiating bundles of prisms referred to before. The green prisms are fresh in color and appearance, and are usually distinctly dichroic, dark green when the prism is parallel to the chief section of the nicol, yellowish-green at right angles to this position. Extinction is nearly parallel, but angles of $4\frac{1}{2}^{\circ}$ occur. The larger crystals sometimes have sharpened ends. The mineral was at first taken for hornblende, but is no doubt aegyrite.

The other mineral forming radiating bundles is probably plagioclase, clearer parts showing twin lamellae, whose angle of extinction, however, could not be sharply determined owing to the small size of the lamellae. Many of these plagioclase strips are reddish-brown and almost opaque, with particles of brown iron ore.

The only other primary mineral observed, except a few needles of apatite, is the isotropic base in which the crystals

it referred to are embedded. It is clear and transparent, with me dusty spots, however, and has not the look of ordinary lcanic glass. With high powers a delicate, but distinct, sys n of cubic cleavage lines can be seen, proving that the mineral isometric and therefore probably analcite, though no crystal rms were observed.

An attempt was made to isolate the glassy mineral with a avy solution, analcite being lighter than any other rock form g mineral belonging to eruptives, and it was found that 17 er cent. of the powder floated when gypsum was used as an dex (spec. grav. 2.32); but when examined with the micro ope the powder was found to contain doubly refracting por ons embedded in the isotropic ones, and some isotropic portions ere noticed associated with the heavier minerals. Some of the ck was then treated with strong hydrochloric acid, when artial gelatinization took place, and it seemed wise to reduce e whole to dryness to render the silica insoluble. It was und that 27.76 per cent. of the whole weight went into solution, mitting, of course, the silica of the mineral which gelatinized hen treated with acid. A second portion treated in the same ay as a check gave 30.35 per cent. of soluble matter. Probably he first portion taken contained more of the sphaerulitic parts han the second. An analysis of the soluble part made by myself ave the following results:

Al_2O_3	10.90
Fe_2O_3	3.13
CaO	1.03
MgO	trace
Na_2O	6.60
K_2O	not det.
H_2O (at 100°)	.69
H_2O (at red heat)	4.85
CO_2	.93
	28.13

We may assume that the only minerals in the rock which uld be appreciably dissolved by HCl are analcite, limonite,

and calcite. If we subtract the lime and carbonic acid, as forming calcite, and the ferric oxide with a proportionate amount of water (.45 per cent.), as forming limonite, we have left the following:

Al_2O_3 - - - - -	10.90	.107 = 1
Na_2O - - - - -	6.60	.106 = 1
H_2O (at red heat) - -	4.40	.244 = 2.28

Reducing to molecular ratios, alumina and soda are equal, and water stands at 2¼, proportions that correspond to those of analcite, except for a little too much water.

If the alumina in analcite equals 10.90 per cent. the corresponding amount of silica, four molecules, is 25.49 per cent., and the whole percentage of analcite in the rock is almost exactly 47, nearly one half. In the second part treated with acid, when 30.35 per cent. proved soluble, the amount of analcite must be more than half the whole weight of rock taken If we subtract the percentages of substances found in the first portion of rock dissolved in hydrochloric acid from the results of the complete analysis, and also the proper amount of silica to form analcite with the alumina, soda, and combined water, we shall have left the materials forming the insoluble ingredients of the rock.

The complete analysis given below was made by Mr. H. W. Charlton, his results being put in column I. In column II an analysis by Dr. Mann of cancrinite-aegyrite-syenite from Siksjö-Berg in Dalarne[1] is given because of its rather close resemblance to No. 1; and in column III an analysis of analcite-basalt from the Basin, Colorado, by W. F. Hillebrand.[2]

A little more than 46 per cent. of the rock remains unaccounted for by the partial analysis; and if we suppose the whole of the potash to belong to orthoclase and the unused portion of iron oxide (1.40 per cent.) to belong to aegyrite, we have left

[1] Neues Jahrbuch für Mineralogie, 1884, II, p. 193; as quoted by ZIRKEL, Lehrbuch der Petrographie, Band II, p. 410.

[2] WHITMAN CROSS, an Analcite-Basalt from Colorado, JOUR. GEOL., Vol. V, No. 7, 1897, p. 689.

	I	II	III
	52.73	51.04	45.59
		.29	1.32
			.03
	20.05	20.47	12.98
	3.43	1.89	4.97
	.99	2.19	4.70
			.14
	3.35	2.62	11.09
			.12
	.11		.13
	.17	.97	8.36
	4.77	3.52	1.04
	7.94	11.62	4.53
100°)	.69	5.85	.51
red heat)	4.85		3.40
	trace	.27	.91
			.05
	.93	.62	
	100.01	101.35	99.87
av.	2.466	2.46	

alumina, lime, and soda nearly in the proportions required ɔradorite (Ab. 2 : An. 3), though the lime and soda are one third in excess of the amount required, the excess less than 1 per cent., however.

mming up the results arrived at, the minerals forming the ave the following percentages :

Analcite	47.00
Orthoclase	28.24
Labradorite	13.00
Aegyrite	4.04
Limonite	3.59
Calcite	1.96
	97.83

this computation moisture removed at 100°, unimportant tages of magnesium and barium oxides, etc., amounting o 1.47 per cent., have been neglected.

e composition of the rock as shown by the analysis differs from that of analcite-basalt, as may be seen from a com-

parison of columns I and III, the latter being more basic, containing less alumina and alkalies, and far more lime and magnesia. It corresponds fairly well, however, to the composition of nepheline syenite, the only important difference being in the amount of water. The syenite from Dalarne, whose analysis is given in column II of the table, having its nepheline weathered to a hydrous mineral, resembles this rock closely in composition, the only important difference being the larger percentage of soda. In their unusually low specific gravity, 2.46, also the two rocks are alike.

One naturally expects to find the dike containing the rock above described in connection with some boss of nepheline syenite; but the slight examination hitherto made of the region by Dr. Bell and myself has not disclosed any area of that rock.

If the analcite rock of Heron Bay had a granular texture, it would appropriately be named analcite-syenite, after the analogy of nepheline-syenite; but its peculiar structure of spherical groups of orthoclase embedded in a ground of analcite containing radiating bundles of plagioclase laths and aegyrite needles sets it quite apart from the syenites. It will probably be wise to give it a separate name, and Heronite, from the name of the locality where it occurs, is suggested as suitable.

Heronite may be defined as a dike rock consisting essentially of analcite, orthoclase, plagioclase, and aegyrite, the analcite having the character of a base in which the other minerals form radiating groups of crystals. The analcite clearly represents the magma left after the crystallization of the embedded minerals; and it is evident that it can be formed only from a magma highly charged with water, and therefore under pressure. It is equally evident that Heronite, like other analcite rocks, cannot be an effusive, since under those circumstances the water would escape;[1] and that its nearest relatives among effusive as well as plutonic rocks are to be found in the group containing nepheline.

A. P. COLEMAN.

[1] Cf. PIRSSON, Analcite Group of Igneous Rocks, JOUR. GEOL., Vol. IV, No. 6, pp. 686–688.

CORUNDIFEROUS NEPHELINE-SYENITE FROM EASTERN ONTARIO

A CONSIDERABLE area of nepheline-syenite was discovered ›out six years ago in Dungannon township, Hastings county, ntario, by Dr. F. Adams, who described the rock briefly in his Report on the Geology of a portion of Central Ontario," and ore fully in the *American Journal of Science.*[1] In 1896 corun-ım was found in the same region by Mr. W. F. Ferrier, and in ıe following year Professor W. G. Miller was instructed by Mr. rchibald Blue, director of mines of Ontario, to examine and :port upon the corundum-bearing rocks. In the course of his ork it was found that the corundum occurred not only in ordi-ıry syenites but also in nepheline-syenite.[2] In November 1898 ıe present writer examined an outcrop of the latter rock for ıe Bureau of Mines on York branch of Madawaska River at ıe northeast corner of Dungannon township or just within Car-›w, several miles from Dr. Adams' localities, and presenting a umber of new and interesting features.

The rock forms a ridge running nearly north and south for bout 350 yards with a width of about 20 yards, and having a ell defined schistose character, so that at first sight it would be alled gneiss. It is light to dark gray in color, the darker layers ontaining much biotite, the lighter ones more nepheline and ›lagioclase. On much of the weathered surface numbers of mall crystals of corundum stand out, having resisted weather-ng better than the other constituents. In hand specimens of he unweathered rock, however, the corundum is scarcely noticed, ınd the rock has quite the appearance of fresh gray gneiss, the ıepheline looking like quartz.

[1]Geol. Surv. Can., 1892–3, Part J, p. 5; Am. Jour. Sci., Vol. XLVIII, July 1894, ›p. 10–18.

[2]Bur. Mines, Ont., Vol. VII, pp. 210–212.

Near the southern end of the ridge an irregular dike a few feet wide crosses the gneissoid rock, reminding one of pegmatite. It is white and consists of immense individuals of nepheline and muscovite, often several inches or even a foot long, with small patches of blue sodalite. No feldspar was seen in the dike, unlike examples described by Adams,[1] and no corundum was found in it.

As usual in nepheline-syenites there is great variation from point to point in the rock, easily seen on weathered surfaces and still more marked in thin sections. Adams finds, as essential ingredients of the outcrops near Bancroft, nepheline, plagioclase, and biotite or hornblende in small amounts; but scapolite and calcite usually occur, as well as various minor accessory minerals. Thin sections from the locality here described show more variety in constitution. All the minerals mentioned, except hornblende, occur, and the feldspars include orthoclase and also a little microcline as well as microperthite. The soda-lime feldspars are generally present in much larger amounts than the potash feldspars, and seem to have a wide range in composition as determined by optical means. A few have angles of extinction of 4° or 5° from the twin plane and appear to be albite as in the rock examined by Adams, others having a very small angle are probably oligoclase, while a considerable number range from 17° to 25° indicating labradorite. Some have broad and sharply cut twin lamellae, others very narrow and obscure ones. All the feldspars are beautifully clear and fresh as a rule, much more so than those of the associated Laurentian gneisses and granites.

The nepheline also is generally very fresh and, as mentioned by Adams, has not the color nor oily luster of eleolite, though it seldom shows crystal forms. Large individuals often contain inclusions, minute crystals of hornblende, of biotite, and long rows of tiny dots of a transparent doubly refracting mineral. Calcite inclusions sometimes occur completely enclosed in fresh looking nepheline. In one example the somewhat weathered nepheline contains crowds of slender transparent fibers or

[1] Ibid., p. 11.

'hat bent cords, having a little the look of apatite but with ll angle of extinction, perhaps tremolite. Occasionally ıposition products occur along fissures, having the appear- ıf kaolin but without any distinct structure.

apolite is found in about a third of the sections, sometimes t to the exclusion of other colorless ingredients and has ok of a primary mineral. Its anhedra meet the adjoining ar or nephéline in a sharply defined way with no hint of ering in the latter minerals. Muscovite is a very common tutent of these rocks, being found in more than half of ıin sections examined, generally as large primary looking duals, sometimes associated with biotite though often with-

Biotite is practically the only dark mineral in the rock, lende not having been observed. As in the specimens ned by Adams, it is very dark in color and has a very axial angle. Augite was found as small blue-green anhe- ı one section only. Magnetite was not found, and apatite are.

he most interesting accessory mineral is corundum, which times occurs in fairly well formed barrel-shaped crystals an inch in length, but is usually smaller and often forms minute rounded grains. Its color is gray or less often pale h. Owing to the hardness of corundum it was found diffi- to prepare sections rich in crystals and only two have been ed. Under the microscope their high refractive index and r thickness than the rest of the section cause the corundum to stand out sharply. They are apt to be arranged in s in association with muscovite, often completely enclosed

ough the rock here described has a well marked schis- cture, there is nothing in its microscopic characters to shearing or crushing, no mortar structure nor granula- seldom even undulatory extinction to hint at a state of he rock as a whole is hypidiomorphic granular, and rundum none of its constituents show much tendency ne form.

The coarse-grained dike with its individuals of nepheline half a foot wide is not easy to study in thin sections. The nepheline proves under the microscope to have been slightly fractured, very narrow fissures being filled with a rather brightly polarizing mineral, perhaps feldspar. The few inclusions are much like those of the nepheline in the schistose rock, but in one section rather large portions of muscovite are enclosed. The large crystals of pale lavender muscovite have no unusual characters except their often perfect idiomorphy as against nepheline and sodalite. The crystals are not hexagonal in cross section but four sided having one angle of about 60°. The basal cleavage is somewhat inclined to the prismatic edges, though a series of pyramids having a very long C axis makes it difficult to determine the angle. In thin sections cut across the cleavage this muscovite has an extinction angle of 3° to 5°.

If single thin sections were to be diagnosed alone four quite distinct types of rock could be described from this outcrop; a nepheline-muscovite rock; a rock made up chiefly of scapolite and muscovite with a little biotite, plagioclase, and nepheline; a rock containing about equal parts of plagioclase and nepheline with some mica; and a rock consisting of orthoclase, microcline and nepheline with some mica. There are, however, transitions between these varieties, and it would be unwise to split up what is so evidently a geological unit into rocks of different names when the whole is so well defined in general character, though each hand specimen shows differences from its neighbors.

No analysis has been made of this rock, but one specimen yielded nearly 10 per cent. of corundum in a heavy solution. As there was no magnetite nor other heavy mineral present the separation was very complete, corundum having a much higher specific gravity than the other ingredients. Since every mineral present, except the trifling quantity of calcite and apatite, contains alumina, nepheline in particular to the extent of more than 30 per cent., this oxide must occur in very large amounts. On the other hand iron oxides must be very low, since the only iron-bearing constituent is biotite.

A specimen of nepheline-syenite was obtained from Lancaster's farm, some miles west of the locality just described, from a small outcrop showing no schistose structure. It is coarser grained, but of the same color and general appearance as the rock from York branch. Thin sections show, however, that it has been subjected to shearing forces, since there is a granulation round the larger pieces of feldspar and nepheline suggesting mortar structure. Nepheline is present in large amounts and also a peculiar type of microperthite having long fibrous looking inclusions of one feldspar in another. the main mass being in parts very finely striated (anorthoclase?) with twin lines making an angle of about 23° with the most marked cleavage. Oligoclase and biotite occur in smaller amounts, the latter as usual very opaque. Some of its outer scales weather to a bronze-brown color, are dichroic, and have the optical axes much farther apart than in the fresh mica.

Specimens of a medium-grained white rock dotted with darker minerals come from a locality not visited by the writer, in Methuen township, Peterboro county, and are interesting as containing many dark brown corundum crystals having a bright bronze luster on basal partings, as well as minute crystals of magnetite.

Thin sections of one specimen disclose chiefly plagioclase, finely striated and with a low angle of extinction from the twin plane; a little microcline, nepheline and muscovite making up the rest of the rock. Sections of another specimen very similar in appearance contain more muscovite and a large amount of nepheline, or rather of a turbid decomposition product, confusedly scaly or fibrous, having high double refraction. The mineral seems to have parallel extinction, fuses readily without intumescence to a white glass, and gives water in the closed tube, so that it is no doubt a uniaxial or rhombic zeolite, perhaps natrolite. The corundum is very opaque so that only minute particles of crushed crystals can be studied satisfactorily. It contains many inclusions of two kinds, slender black needles lying parallel to one another, and brownish-red strips and plates

somewhat irregularly shaped and placed. The latter are probably hematite and produce the bronze luster seen on basal planes of the corundum. Extinction is parallel to the needle-like inclusions, and there is a rather strong dichroism, violet when the needles are parallel to the chief section of the lower nicol and reddish-brown in the opposite position. Some fragments, no doubt parallel to the basal plane, are not dichroic.

The first of the two specimens might be named a plagioclasite (anorthosite contains a more basic feldspar) if taken separately, but the second does not differ from typical examples of the York branch nepheline-syenite except in the complete weathering of its nepheline, and probably both are varying forms of the same rock mass.

Through the kindness of the director of the Bureau of Mines specimens of corundum rocks from Raglan township in Renfrew county, about twenty miles northeast of Dungannon, have been placed at my disposal. One is white, somewhat schistose, and much like the Methuen specimens except that it contains biotite, and that the pale greenish corundum crystals are almost an inch in diameter and have no bronze shimmer on basal planes. Under the microscope it is found to consist mainly of plagioclase (oligoclase) and biotite, the latter pale greenish-brown, faintly dichroic and with a small axial angle. There are also a few large patches of colorless muscovite having a large axial angle. The specimen has the mineralogical composition of a diorite, though of a very unusual character; but Professor Miller states that nepheline-syenite occurs close by, apparently part of the same rock mass, though not so highly corundiferous.[1]

These white rocks were taken for limestone by farmers of the region, and an attempt was made to burn them for lime, of course, in vain. Hand specimens, partly fused, were taken from the kiln and supposed to be nepheline-syenite, many of them doubtless having that composition; but the one provided for microscopic examination contains no nepheline. It is evidently part of a bowlder and is schistose and pale gray to white on the

[1] Bur. Mines, Ont., 1897, p. 222.

surface, but mottled bright blue and white where broken. Under the microscope the rock is found to consist of scapolite, sodalite and biotite with a very little orthoclase. The scapolite forms the greater part of the rock, the spaces between its anhedra being filled with sodalite; the latter blue throughout when in small portions, but only on the edges when in large ones, the center being colorless and isotropic. The bowlders are said by Miller to be blue only after being burnt in the lime-kiln.

The biotite is deep red-brown in color, has a high absorption and a wide axial angle, perhaps the result of heating; just as many dark biotites turn brown by weathering and have a wider angle between the optical axes.

There are small quantities of an unknown mineral present, white, transparent and having a low double refraction, so as to give only dull blue or purple tints between crossed nicols. Two or three sections of it show an axial image consisting of a black cross opening out about as far as in many biotites, but without colored rings. It is optically positive.

About eleven years ago the writer collected a considerable number of specimens of nepheline-syenite from drift bowlders in the neighborhood of Cobourg, Ontario, which lies about south-southwest of the localities referred to above and from fifty to a hundred miles distant from them. At that time nepheline-syenite had not yet been reported from the province.[1] In a general way these specimens correspond in appearance and composition to those that have been described, though a number of additional minerals occur in them, the more important being hornblende, augite and garnet, both of the ordinary kind and melanite, the brown variety. Only one of the specimens collected then contains corundum; and it, though closely like the others in appearance, shows little or no nepheline and resembles in mineralogical constitution, one of the specimens from Methuen. The purplish-gray corundum crystals are quite large, and thin sections show the same needlelike inclusions

[1] Trans. Roy. Soc. Can., 1890, pp. 14–18.

and dichroism as the Methuen crystals, but not the hematite plates.

As there is not much doubt that the Cobourg drift bowlders originated in the nepheline-syenite region to the northeast, they have been referrèd to here and may be considered in connection with the rocks previously described.

In spite of the great variations in mineralogical composition to be seen in hand specimens all the rocks referred to have much in common; they are white to gray in color, generally schistose, often corundiferous, and present the same general habit, so that in field work they are naturally thrown together as nepheline-syenite and can be sharply distinguished from adjoining Laurentian gneisses, granites, and syenites. While not all of them contain corundum in large amounts they serve as a general guide to the discovery of the corundiferous rocks and are so used by prospectors for that mineral. Some of the ordinary syenites of the region, however, contain corundum also, and the largest crystals found occur in them.

Just why the magma which has solidified into the group of rocks described above should be so versatile in regard to mineralogical composition is not easily explained; but no other rock known to the writer shows so great a variety of types within short distances as may be found in the nepheline-syenites. It may be that experiments such as those of Morozewicz[1] will give the clue to this variability, which seems to depend on the large proportion of alumina in the original magma. The corundiferous varieties of nepheline-syenite represent magmas supersaturated with alumina but not saturated with silica.

A. P. COLEMAN.

[1]See Review by T. A. JAGGAR: JOUR. GEOL., 1899, Vol. VII, No. 3, pp. 300, etc.

THE EFFECT OF SEA BARRIERS UPON ULTIMATE DRAINAGE

THE causes which determine the location of river courses in the neighborhood of their discharge into the sea, where the currents are slow and their power of erosion small, are often quite insignificant.

If, however, a stream once becomes established in any given course, and the region through which it flows becomes elevated, its sluggish current at once becomes active and forms a valley of greater or less depth. Its tendency through subsequent changes in the land level is to remain in the valley approximately as originally formed. This tendency is especially strong if this original valley is parallel with the strike of the strata.

It is not the purpose of the present paper to discuss the development of intricate drainage systems along structural lines, and through long periods of time, but simply to suggest that a drainage system may sometimes have a portion of its course fixed, by spits and barrier beaches along the coast line, at the same time that the sediments which are to form the rocks of its future drainage area are being deposited; and also that the drainage when established thus early may remain more or less fixed through its subsequent history.

Along coast lines generally, and especially along those of gently sloping coastal plains, spits, bars, and barriers are more or less common. For our present purposes these may all be spoken of as barriers, and so far as the present paper is concerned it does not matter whether they are composed of sand, gravel, or coral; neither do the forces by which they are built up need to be discussed.

The lagoons between the barriers and the shore vary in length with the barriers, from a few hundred yards to many miles. Such lagoons are parallel to the shore and usually

almost at right angles to the course of the drainage entering them.

The drainage from the land must pass through these lagoons, often for almost their entire length before it can reach the sea through gaps in the barriers or around their ends. Thus it happens that long, low barriers, often of soft sand, and of insignificant height, which if inland would be slight obstacles to erosion, often control large drainage areas (Fig. 1).

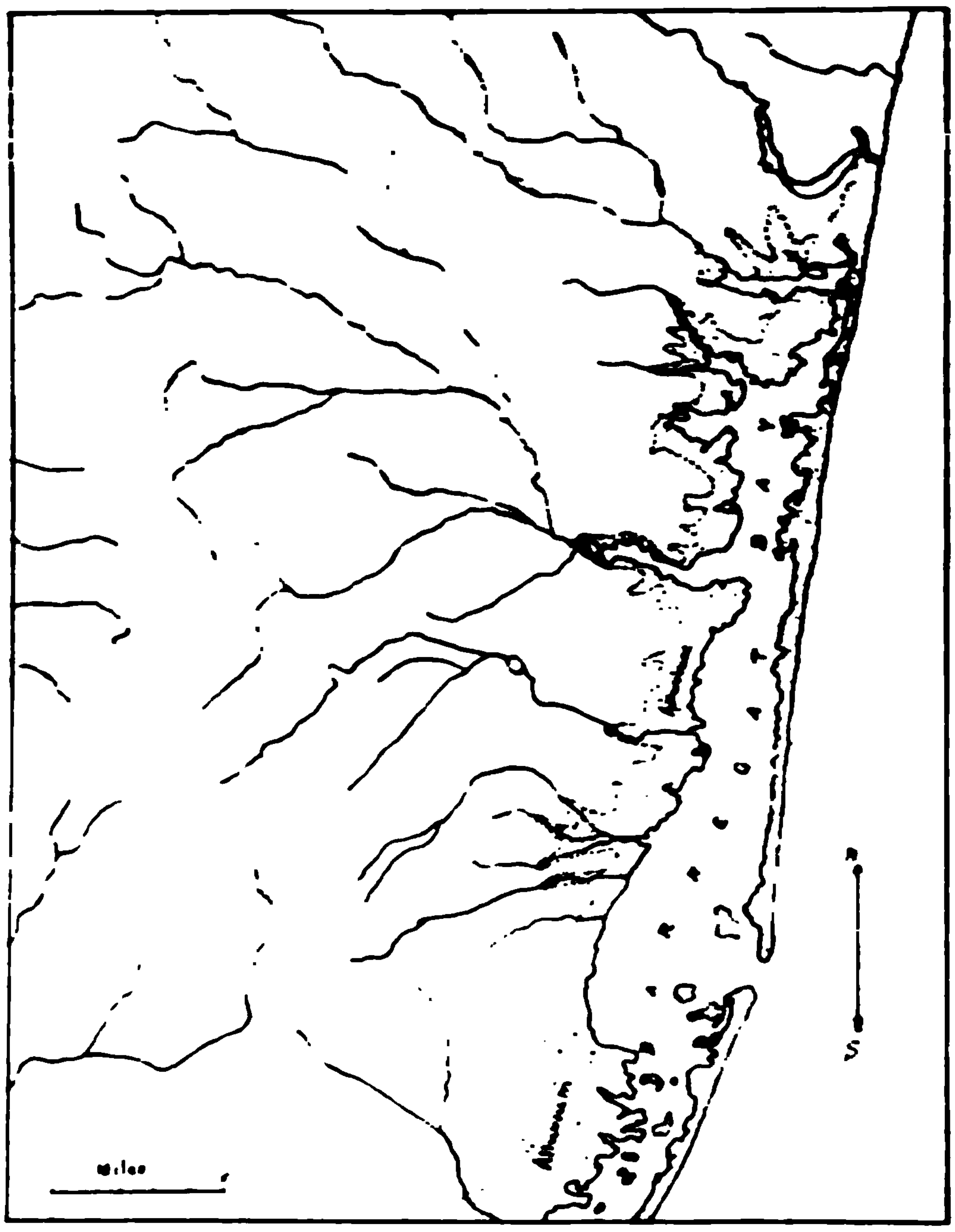

Fig. 1.—Barnegat Bay on the coast of New Jersey. The drainage, at present deflected by the barrier, passes through the bay and into the ocean.

Excellent examples of drainage controlled by barriers are to be found developed to a greater or less extent along the coasts of almost all countries. Along our own coasts the most marked examples are the streams flowing from Texas into the Gulf of Mexico; Indian River along the east coast of Florida; and the

reams emptying into Albemarle, Pamlico, and neighboring ounds. The drainage in all these localities is deflected many iles. Many less marked instances of deflected streams may be een upon almost any map of a long coast line.

The writer's attention has been called by Dr. J. C. Branner o the stone reefs along the coast of Brazil. These reefs bear

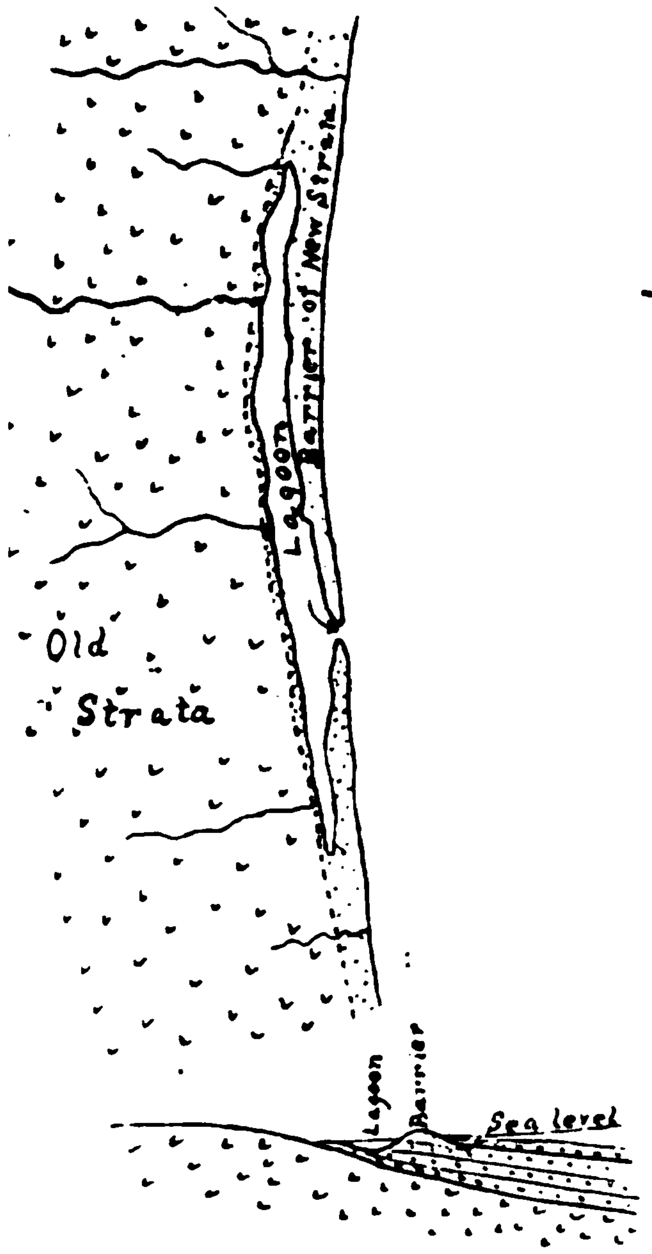

FIG. 2

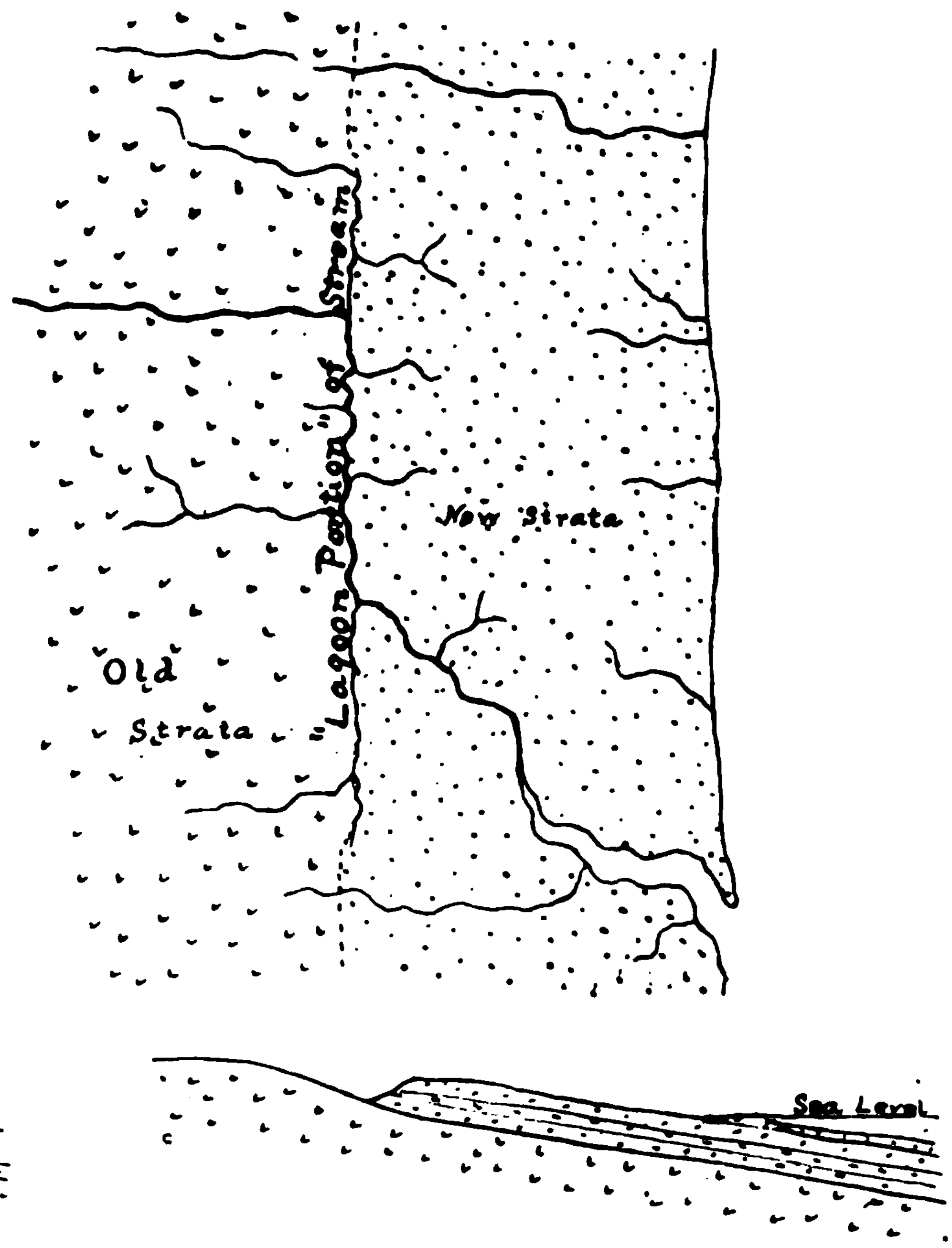

FIG. 3

FIG. 2 shows a shore line whose drainage is deflected by a barrier. The cross-section shows the relations existing between the barrier, lagoon, new, and older strata.

FIG. 3 shows the arrangement of drainage, as represented in Fig. 2, after the elevation of the land. The "lagoon portion" of the stream is here shown as being directly along the contact between the newer and older groups of strata.

the same relation to the shore as ordinary sand barriers, and they are probably old barriers whose sands early became cemented. In such cases of early solidification, the "lagoon" portion of the resulting land stream is, of course, held in position much more firmly than in the case of loose sands.

Shore deposits usually have a slight seaward dip. It happens, therefore, that the streams entering lagoons behind barriers may not only have their courses determined early in their history, and that subsequent erosion after the land becomes elevated tends to deepen the channel in the position determined, but also that this position is parallel with the strike of the strata. The subsequent tendency of the stream, therefore, is to remain in this original course established for it by the lagoon, as shown in Figs. 2 and 3.

If the coast, along which such stream deflection occurs, happens to be rising, or if the barriers are being added to from the seaward side, the barriers, at first narrow and low, may become gradually wider and higher and finally form a considerable land area. In this new area a new drainage system will develop, a portion of it being drained landward to its old lagoon, the rest draining either directly or through a new lagoon, into the ocean, as shown in Figs. 3 and 4.

If the land level remains unchanged, the lagoon is left inland and controls the drainage of the region on its landward side with little or no tendency toward erosion. If, however, the land becomes slowly elevated, the old "lagoon portion" becomes an active stream and cuts out a channel in and along the strike of the new rocks. As the shore becomes more and more elevated, and the stream is left further inland, this portion of the channel becomes more firmly established in its course. Thus it becomes an inland stream, which had a greater or less portion of its length originally established parallel with the coast, with the contact between groups of strata and also with the strike of the rocks, and not across the strike or outcrop, as is so commonly taken for granted for the original courses of streams. (Fig. 3.)

It is obvious from what has been said that the "lagoon portions" of streams will be determined in a direction approximately parallel with the general direction of the contacts of the newly-formed geologic groups; they may be directly along this line, or they may be several miles on either side of it.

Fig. 1 may be taken as a type to illustrate this. Here the

barrier of "alluvium" enclosing Barnegat Bay on the coast of New Jersey is from three to five miles from the contact between the "alluvium" and the older beds of gravel, sands, and clays. If Barnegat Bay were silted up by sediments from the landward

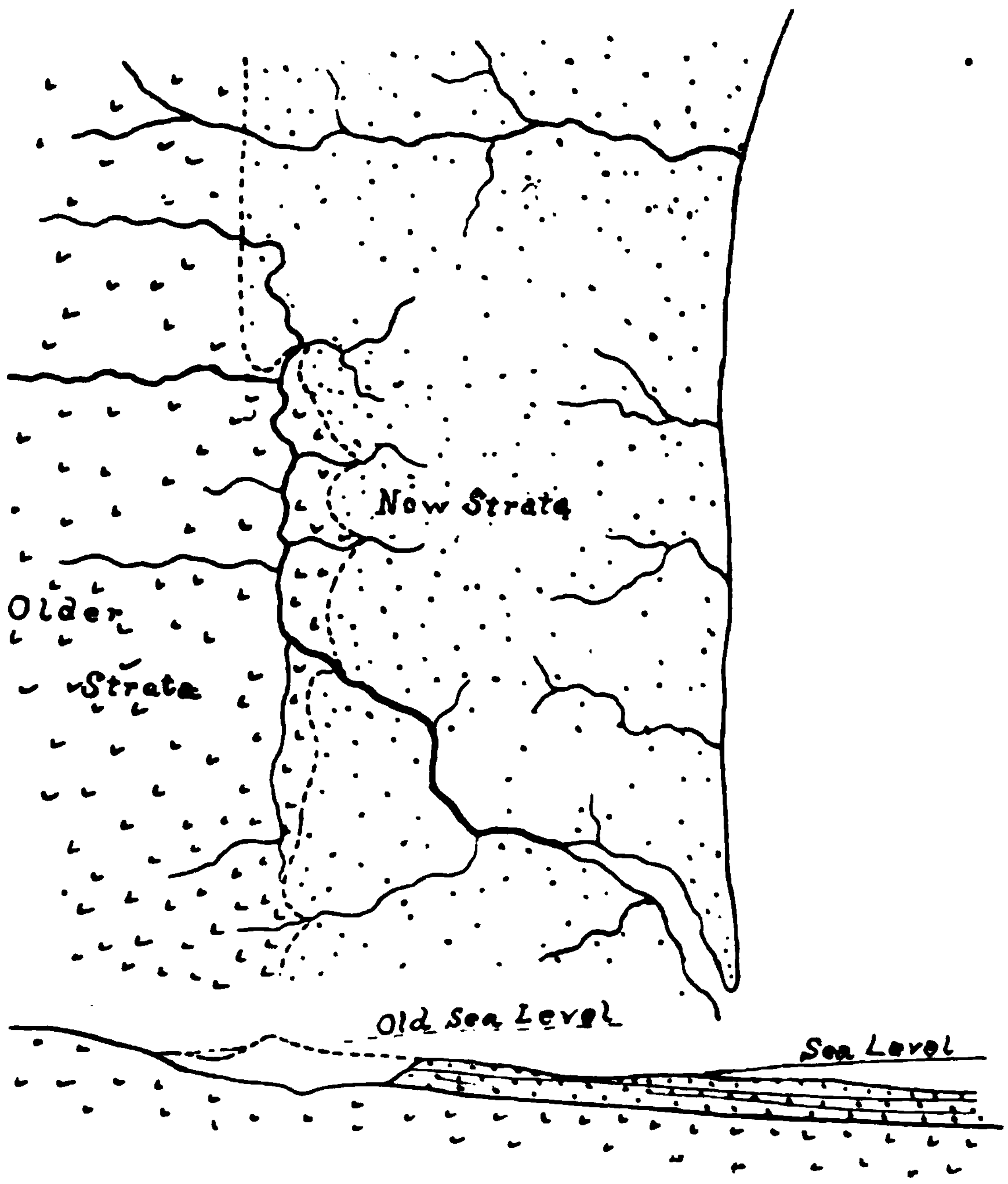

FIG. 4.

FIG. 4 is a further development of Fig. 3; the "lagoon portion" of the old stream having for the most part settled itself down in the underlying strata. The contact between the newer strata and the older being shifted seaward by erosion, the line of contact is some distance to the seaward from the stream. If the underlying older beds are very hard, the stream might continually shift itself along the line of contact, instead of cutting down into the hard beds below. A part of the old "lagoon portion," instead of cutting down into the underlying rocks, is shown as having been shifted down the dip of the newer beds, and as flowing parallel with the contact but to the seaward of it.

side, its lagoon might be shifted close up against the barrier. If, under these circumstances, this coast should be elevated and the shore line should be shifted some miles seaward, the "lagoon portion" of the resulting stream would be approximately parallel

to the strike of the rocks, and also to the upper and lower contacts of the particular group of strata formed, though several miles removed from either of those contacts.

On the other hand, a stream flowing parallel with the contact and not far removed from it might cut down completely through the series of strata by which its course was originally determined, and reach the older underlying rocks. Under such circumstances the newer beds through and along the edges of which the stream originally flowed, would in time be removed by erosion for some considerable distance from the line of contact, as shown in Fig. 4.

It is, of course, difficult to point with certainty to streams at present far inland that have had their courses originally determined in the manner suggested. This explanation offers itself, however, for streams that now flow parallel to and in the neighborhood of contacts between sets of beds of different ages, as also for streams flowing parallel to preëxisting coast lines. It is not improbable that many streams flowing with the strike of strata, and whose courses have been attributed to stream capture, owe these courses to the simple fact of their having been primarily established in that position as here suggested. Many such streams may be seen on any detailed geologic and drainage map of our eastern and southern coastal region, though they are by no means limited to such regions.

This explanation is suggested as a probable one in accounting for the sudden southwest deflection of the Delaware River at Bordentown, N. J., and the Potomac near Washington, and for the sudden turn of the Susquehanna into the upper portion of Chesapeake Bay, which may be considered as its extension.

The same explanation is suggested also in regard to the Tennessee River for the lower portion of its course where it flows northward through west Tennessee and Kentucky.

Black River, in Arkansas, flows for almost its entire length near the line of contact between Tertiary and Paleozoic rocks. This stream may have had its course originally established,

arallel to the old coast line in much the same way that Indian Liver, Florida, has its course fixed at the present time.

Many others could be mentioned, but these serve to show he character of the drainage that might be expected from the uggested causes.

It is not meant to imply by the foregoing remarks that all arriers that may be formed will exercise control on the ultimate lrainage. Probably most of those formed are quickly destroyed s the shore line encroaches or recedes. It is hardly reasonable o suppose, however, that all barriers formed through past eologic ages have been disposed of thus easily.

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shows conclusively that the forward growth of the delta must have been extremely rapid, for an ice margin bathed constantly by the waters of the sea or a glacial lake could not long remain stationary. That the time of growth was a short one was early urged by Davis and is generally admitted by those familiar with such deposits. Even in the case of many of the larger plains it seems clear that the time of growth should be measured by months rather than by years, and the assumption that they are the result of a single season's stream work is not unwarranted.

If this view is accepted, the question at once arises as to whether the plain represents the deposits of the whole, or only a part of the season of ablation. The first thought would naturally be that they represent the whole, but on more careful consideration this seems less probable. The observations upon sand-plains show that there was practically no backward melting of the ice during their formation. The retreat, then, must have taken place under conditions more favorable to the melting or breaking up of the margin of the ice sheet than those existing during the formation of the plains, and to maintain that the sand-plains represent the whole of the summer periods of melting would mean the reference of the periods of retreat to the winter season, a conclusion not in harmony with the laws of nature.

As an alternative, it might be considered that the sand-plains represent summers of only moderate warmth, while the periods of melting were characteristic of seasons of a considerably higher average temperature. The melting of the ice, the discharge of the glacial streams, and the amount of detritus, would all have been increased under such conditions. In reality we find that often only a slight deposition of sediments took place between the stages of sand-plain growth, especially when plains are but short distances apart, as in the case of the Barrington and Nyatt Point sand-plains, hereafter to be described. Here the intermediate area is practically free from deposits of an inter-sand-plain period, indicating that the retreat of the margin took place during a period when little detritus was being set free from the ice by ablation.

A consideration of the conditions obtaining during the closing stages of the ice sheet leads to the conclusion that the periods or stages of the retreat in the vicinity of the Barrington Plain were characteristic of spring, corresponding more or less roughly to the present months of March, April and May.

Following is a summary of the reasons: (1) The insignificant development, or complete absence of back-sets in the most typical sand-plains, show that the retreat was not characteristic of the summer period. (2) The fall represents a waning, and the winter a cessation of all the conditions that can in any way be regarded as favorable to the ice retreat. The retreat cannot, therefore, be regarded as characteristic of these periods. (3) Though the actual precipitation may have been no greater than in the winter months, precipitation in the form of rain probably reached its maximum in the latitude of northern United States during the months of early spring. It is well known that water attacks ice much more rapidly than air at the same, or even higher temperatures. The period of spring rains must, then, have been one of rapid ablation. (4) The precipitation of the winter months must have been mainly in the form of snow, which according to Upham, would reach a maximum within a comparatively short distance of the margin. Under the influence of the spring rains the deep snow must have rapidly melted, helping swell the glacial, and especially the superglacial streams to sizable torrents. The rapidity with which such superglacial streams cut into the ice is well shown by some of the superglacial streams of Greenland which, though usually short and of small size, have often sunk to some considerable depth into the ice. Such streams near the margin of the waning ice sheet would have rapidly cut through the ice to the very bottom, leaving detached pieces of various sizes and shapes which, however, would melt with comparative rapidity. (5) The streams during the spring being fed mainly from the melting snow or direct precipitation would carry a proportionally small amount of sediment and the detritus instead of being deposited at a single point as in the case of the sand-plains, would be distributed

over a large area as an inconspicuous sheet. (6) In the summer the ice margin would become stationary and the deposition of the detritus, which was derived almost entirely from the ablation of the débris-laden ice, would be concentrated at definite points.

Although from the above considerations it seems reasonable to refer the shorter ice retreats between sand-plain stages to the spring months, it is probable that the longer retreats represent longer periods, perhaps in some cases years in length. In this case the absence of inter-sand-plain deposits may be more seeming than real, because of the sheet form of such deposits.

TIME ELEMENT

If the months of December, January, and February are eliminated, as there can be no doubt they should be, from the time of sand-plain growth, the retreat of the ice and the deposition of the plain must have taken place in the remaining nine months. The distance between sand-plain stages varied from a fraction of one up to several miles, and three months certainly seem none too long a time for such a retreat. If this be so, the sand-plains, or at least those of modern size, must have been formed in the six months still remaining.

A study of the conditions now existing in the larger glaciers of Alaska, showed at once that such a rate of deposition was by no means improbable. A calculation based on such conditions could not fail to be of interest, and would give valuable indication as to the probability of the general estimates. The results showed an unexpected and surprisingly close agreement with the estimates.

Basis of calculations.—Evidence as to the time of formation of sand-plains is afforded; (1) by the bulk of the sand-plain itself, and (2) by the bulk of the accompanying clays, which from their mode of formation, are known to be simultaneous in development and coextensive as to time. The time estimate is obtained by dividing the bulk by the daily discharge of sediment of the glacial stream. To find this discharge of sediment

it is necessary to know the area of the cross-section of the stream, the velocity of its flow, and the percentage of sediment carried. The first two values are indicated by the esker and the

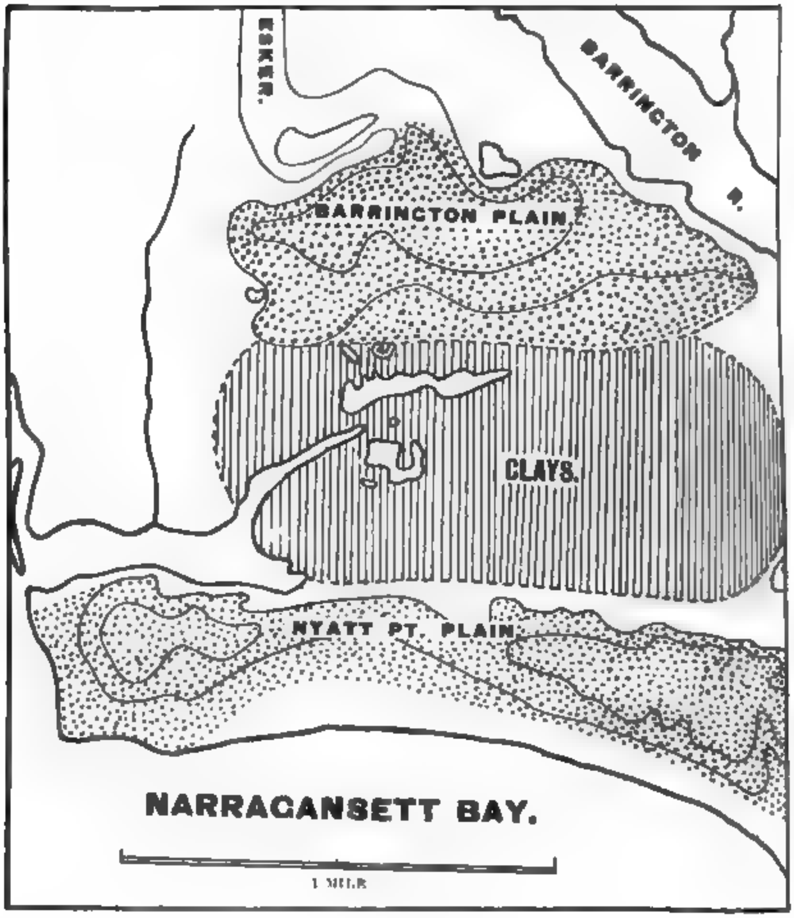

FIG. 1.—Map of Glacial Deposits, Barrington, R. I.[1]
Contour interval, 20 feet.

material of which it is composed. The latter must be estimated from observations upon glacial streams existing under similar

[1] The geology is taken from map given by Mr. J. B. Woodworth in Seventeenth Ann. Rept. U. S. Geol. Surv., Pt. I, Pl. LXII.

conditions at the present time. Such observations have been made by Wright, Reid, and others in regard to the fine sediments such as make up the so-called glacial clays, and it is upon these observations that the present estimates are based.

Locality selected. — Conditions favorable to a calculation of the time of formation from the extent of the plains, or their associated clays, are in almost every case wanting. In 1896, however, Woodworth described[1] and mapped a series of unusually typical deposits in the town of Barrington, R. I. A visit to the locality showed the conditions to be almost ideal, and admitting of calculations of some definiteness. The clays were selected as a basis of calculation in preference to the sand-plain itself, because of the greater number and reliability of the Alaskan observations upon this class of sediments.

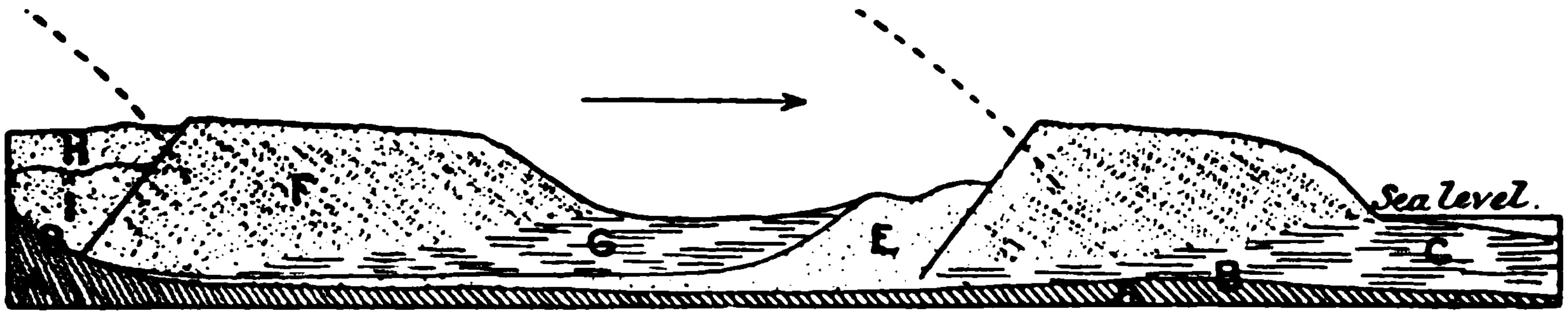

FIG. 2.—Section across Barrington, R. I., showing relations of clays to sand-plains. A, Terrane of Carboniferous age; B, Glacial drift older than Nayatt Point stage; C, Clays contemporaneous with the Nayatt Point sand-plain; E, Gravel and sands deposited upon the melting of the ice along the head of the Nayatt Point plain; F, Barrington sand-plain; G, Barrington clays; H, esker; I, gravel and sands laid down upon the melting of the ice back of the Barrington plain. — J. B. WOODWORTH: *Seventeenth Annual Report U. S. Geol. Surv., Part I, p. 987.*

Barrington clays. — These clays are exposed at the surface over an area of about six tenths of a square mile (Fig. 1). On the south the clays rest against the ice-contact slope of the Nyatt Point sand-plain, while on the north they extend as a gradually thinning wedge beneath the Barrington plain, reaching their northern limit approximately along the ice-contact slope of this latter plain (Fig. 2). The depth of the clays in the vicinity of the railroad, as shown by borings, is about sixty feet. With the exception of one slight break there is a ridge, partly till and

Seventeenth Annual Report U. S. Geol. Surv., Part I, 987, 988; and Am. Geol., VOL. XVIII, 161–164, 391, 392.

partly of modified material, connecting the two sand-plains on the east, and having an average height of about forty feet. On the west there is no marked rise between the clays and the waters of the bay, the latter even at the present time having access to the clays by a fair-sized estuary. The surface of the clays is practically at sea level.

The clays, which vary from gray to blue-gray in color, are composed principally of quartz flour—the ultimate product of glacial scouring—with a comparatively slight intermixture of true clay. Their amount, allowing for the thinning out in various directions, and taking their specific gravity as 2.5, is found to be approximately 95.3 million tons.

Conditions at time of deposition.—The heights of the two sand-plains are about fifty feet and indicate a probable height of water at the time of their formation of at least forty feet above the present sea level. The ice on the north, the ridge on the east, and the Nyatt Point plain on the south would form an inclosed bay, with practically no opening except at the west. Here, however, there must have been an opening something like three fourths of a mile wide and thirty-five to forty feet deep connecting with the sea and allowing a more or less complete commingling of the salt and fresh waters.

Into this inclosed bay emptied, as indicated by its esker, a glacial stream 150 feet wide, with a probable depth of some twenty feet, and a velocity sufficient at times to move pebbles up to six inches in diameter. This would indicate a maximum velocity of a little over six feet per second, but the average material composing the esker would require a current certainly not over five feet per second. The discharge of such a stream would be 15,000 cubic feet per second.

The area of the cross-section of the outlet from the inclosed bay was about 138,000 square feet, or some forty-six times that of the glacial stream. If discharge took place uniformly through the outlet the velocity would have been one and one third inches per second. If the flow of the fresh water took place as a surface current, as would have been the tendency, a somewhat

greater velocity would have resulted, but not enough greater to have prevented the settling of the sediment. The ebb and flow of the tide, which is about four feet, would have decreased the outflow some 25 per cent. during flood tide, and increased it by a corresponding amount during the ebb.

The average distance through which the water would move in its passage from the mouth of the glacial stream to the outlet would be at least a mile. The current, which at the frontal slope of the sand-plain had a velocity, as indicated by the material deposited, of some eight inches per second, would decrease until certainly not over three inches per second at the outlet. Its passage would require fully four hours.

Sediment of glacial streams.—According to Helland,[1] as quoted by Reid,[2] the maximum sediment values of their respective regions are represented by the Unteraar glacier of Switzerland, which carries .142 grams per liter; the Langedal glacier of Norway, carrying .513 grams; and Alangordleck glacier of Greenland, carrying 2.37 grams. Both Wright and Reid found much more sediment in the waters from the Muir glacier of Alaska, the former recording a load which reduces to 12.12 grams per liter,[3] and the latter a load as high as 12.98 grams per liter.[4] As the Alaskan glaciers most nearly represent the conditions obtaining during the closing stages of the continental ice sheet, I have taken Reid's value of 13 grams (actual value, 12.98 grams) as a basis in calculating the time of formation of the Barrington clays.

In all probability the sediment discharged by the streams draining the continental ice sheet was even greater than that of the most heavily loaded glacial streams of today. I have sought to neutralize this difference as much as possible by applying as a mean value to the Barrington deposits the maximum value of the Muir glacier sediments.

[1] HEIM's Gletscherkunde, p. 363.

[2] Sixteenth Annual Report, U. S. Geol. Surv., Pt. I, p. 457.

[3] Ice Age in North America, p. 64.

[4] *Loc. cit.*, p. 454.

Rate of settling.—Recently, in connection with professional work for the Metropolitan Water Board of Massachusetts, Professor W. O. Crosby has incidentally had occasion to determine the rate of settling of the finer portions (*i. e.*, quartz-flour) of both the till and the stratified drift. No definite maximum limit has ever been fixed for the grains of quartz flour, but in the experiments in question this name was applied to that portion passing through a sieve of 170 meshes to an inch. The larger grains are about $\frac{1}{300}$ of an inch in diameter.

In the experiments, the results of which Professor Crosby has kindly placed at my disposal, 5 grams of the quartz flour were introduced at the top of a half-inch tube containing five feet of water. The time of settling was then taken. The results showed that fully 75 per cent. of the material settled within thirty minutes from the time of insertion, and in the majority of cases none whatever remained in suspension at the end of sixty minutes. In other cases a distinct turbidity, probably due to true clay, was still noticeable at the end of this time. This was determined by filtering and weighing, the amount varying from a mere trace up to 10 per cent.

The results show that even in fresh water the settling of quartz flour is very rapid, the greater part settling at a rate of at least ten feet per hour. In the inclosed bay in which the Barrington clays were deposited the water was salt, or at least decidedly brackish, and the rate of settling must have been much increased, especially in the case of the finer material, which, according to W. H. Brewer, will settle as much in salt water in thirty minutes as it would in as many months in perfectly pure water.[1] There can be no reasonable doubt, then, that practically the entire amount of sediment brought in by the glacial stream was deposited within the inclosed bay.

Statement of problem and results.—During a certain stage of the ice retreat from the region of Narragansett Bay, the area now covered by the Barrington clays stood at a level some forty feet below that at present existing, and was covered by a body

[1] Am. J. Sci., III, 29, p. 4.

f salt or brackish water which rested against the ice on the orth, and was practically cut off from the sea on the east by a ll ridge, and on the south by the Nyatt Point sand-plain. Into his body poured a glacial stream with a volume of some 5,000 cubic feet per second, and bearing a load which I have ssumed as a maximum to be 13 grams per liter, amounting to 26,500 tons per day. From experiment it has been found that naterial like that of the Barrington clays settles very rapidly, ndicating that practically the whole amount brought in by the lacial stream must have been deposited within the inclosed area ndicated.

The amount of the clay is some 95.3 million tons. Dividing his by the daily discharge of sediment of the glacial stream, *the ime of the deposition of the clays is found to be 181 days*, or almost exactly six months.

General application.—Though in the sand-plains of different ocalities, the proportion of sand and clay varies greatly, the Barrington deposits taken as a whole probably represent very nearly the average conditions. I am satisfied, therefore, that the results obtained in the case of the Barrington plain, though strictly speaking they are applicable only to this plain, represent fairly closely the time required for the formation of the *average* sand-plain. If, for the reasons given on a previous page (p. 454), the ice retreat is considered as taking place in the early spring, it would follow that these figures represent a maximum, rather than a minimum, time limit. In the case of large plains, however, with areas of several or many square miles it may be possible to consider the period of deposition as extending over more than one season of melting, there being in the meantime either no retreat of the ice margin, or a retreat so slight that the intervening space was completely filled, and the sand-plains united into a single compound plain.

Remarks.—One of the points most strongly emphasized by the results obtained, is the almost incredible amount of sediment discharged by the Barrington glacial stream during the few months of summer activity. The daily discharge of sediment by

this small stream, not over 150 feet in width, was equivalent to 40 per cent. of that of the Mississippi.[1]

The small amounts of the coarse material, compared with the amount of clay, is also a significant feature. It shows fully two thirds of the detritus brought in by the stream was of the finely comminuted quartz flour. The velocity was such that had the current come in contact with the subglacial till to any extent the percentage of coarse material would have been much greater. Its absence indicates, therefore, that practically the entire amount must have been derived from the ablation of the ice. The high percentage of the finer débris contained within the ice is certainly a striking feature.

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[1] J. B. WOODWORTH, *loc. cit.*, 162.

ꟷIE PETROGRAPHICAL PROVINCE OF ESSEX CO., MASS. GENERAL DISCUSSION AND CONCLUSIONS. V.

Analytical methods.—As far as was possible with the means my disposal the methods advocated by Hillebrand[1] were fol-wed, some slight modifications being necessary owing to lack f certain facilities in my laboratory. A word must be said in :cognition of the high character of the work of the chemists f the U. S. Geological Survey. Petrologists generally are eeply indebted to them for the service they have rendered the :ience, not only by the investigation of methods and the very ırge amount of excellent work which they have done, but also ɔr the high standard of excellence which they have set for ther analysts to follow.

Ignition H_2O was determined in dry CO_2. It will be seen ·om the generally low summation of the rocks high in FeO ıat this did not entirely prevent oxidation under the condi-ons obtaining, but the error will not be high. The precipita-on with ammonia was always made twice, and three times in ne case of the basic rocks, in the presence of sufficient NH_4Cl. 'his is of the utmost importance, as pointed out by Pirsson[2] nd Hillebrand,[3] on account of the tendency of MgO to be oprecipitated with the Al and Fe hydrates. Neglect of these recautions has rendered useless many analyses, but it is a point vhich is often overlooked. With one exception, MnO was not letermined, since its amount was apparently small and its deter-nination would have extended considerably the time necessary or an analysis, and hence lessened their number. Alkalis vere, of course, determined by the Lawrence Smith method.

[1] CLARKE and HILLEBRAND. Analyses of Rocks. Bull. U. S. Geol. Surv., 1897.

[2] PIRSSON, JOUR. GEOL., Vol. IV, 688, 1896.

[3] HILLEBRAND, *op. cit*, p. 39.

It must be noted that throughout this paper the terms acid and basic refer only to the relative amount of SiO_2, no connotation of the amounts of the other oxides being implied.

Use of the term petrographical province.—The idea which underlies the general use of this term is that of a region of igneous rocks which possess in common certain characters, structural, mineralogical, or chemical, and in which the characters may vary continuously from one end to the other of the series of rocks represented. The term is usually applied to large areas embracing several centers of igneous activity, which, by their similarity in character, may be presumed to be related. Its application in the title of this paper is somewhat restricted, and therefore open to criticism, but seems justified on the grounds of convenience, the evident relationship of the rocks, and the fact that this region may serve as the type of the still larger New England one.

Chemical characters.—In Table I are given my analyses of the rocks of Essex county, with one by Dr. Eakle, and in Table II the molecular amounts of the various oxides. It is to be borne in mind that all references to the relative amounts of the oxides are to their molecular amounts, and not to their percentages as obtained in the analyses.

The range in composition is very great, the rocks varying from basic gabbro with 44 to acid granite with 78 per cent. of SiO_2. Al_2O_3 varies considerably and is notably higher toward the basic end. The total amounts of iron oxides are rather high, Fe_2O_3 being low and varying little, while FeO is higher, especially so in the basic rocks. MgO and CaO behave alike, being low in the more acid rocks, and suddenly much higher in the basic. The alkalies are abundant, Na_2O more so than K_2O, but, on the whole, do not vary as much as the other constituents.

The rocks as a whole are rather acid, *i. e.*, they contain more SiO_2 than most similar types elsewhere. The granite is decidedly an acid one, the foyaites more acid than most nepheline-syenites, and the same is true of the pulaskites, the akerite

ıd nordmarkite, the tinguaite, sölvsbergite, and paisanite. In ıe basic rocks, on the other hand, the opposite seems to hold ɔo d, that they are more basic than usual.

In the next place they are rich in both alkalis, and Na_2O constantly greater than K_2O. On the whole, however, Na_2O oes not predominate to such an extent as to stamp the region s essentially one of soda rocks, but is sufficiently predominant ɔ determine the character of the types, as shown in the minralogical composition.

In general the rocks are rich in iron oxides, FeO being espeially, and in some cases abnormally, high. It may be menioned that TiO_2 is high, comparatively speaking, and that BaO ɨeems to be absent.

The province as a whole then, may be characterized as one ɔf rocks which are more acid or more basic than normal, high in alkalis, with Na_2O predominating over K_2O, high in iron oxides, especially FeO, rather high in Al_2O_3, and low in MgO and CaO.

Mineralogical characters.—We find the main chemical features well expressed in the general mineralogical composition. Corresponding to the high SiO_2 and alkalis, the prevailing feldspars are albite and orthoclase, with quartz-syenites abundant. The albite molecule is very abundant, giving rise to the characteristic microperthites and the albitic syenites of the litchfieldite and pulaskite types. At the same time the soda-hornblendes and soda-pyroxenes are common. The low CaO forbids the formation of much lime-soda feldspar, which we find to be rare, and even in some of the basic rocks the plagioclase is more albitic than usual.

The paucity in MgO is of great influence. Olivine is rare even in the basic rocks. A striking peculiarity in this connection is the replacement of the deficient MgO by FeO. This gives rise to the presence of varieties of minerals normally magnesian, but which are here largely ferrous instead. This is exemplified by the abundance of the MgO-free biotites, lepidomelane and cryophyllite, as well as the occurrence of the

purely ferrous olivine, fayalite[1] in the granite, and the presence of the MgO-free "glaucophane" molecule in the blue hornblendes[2] of the region.

Discussion of oxide ratios.—In Table II are given, below the molecular amounts, several oxide ratios, which we may next examine, since they serve to differentiate the rocks of the region into groups.

$\frac{Na_2O}{K_2O}$. This ratio is constantly greater than unity, as we have seen, though often closely approaching it. A striking feature is that in ten or eleven cases it is either exactly or very near a whole number; 1 : 1, 2 : 1, 3 : 1, or 6 : 1. In ten others it closely approximates to multiples of a half; 1 ½ : 1, 2 ½ : 1, 3 ½ : 1, or 6 ½ : 1. In only three or four cases does it differ more than about .12 from such figures. There seems to be a tendency for Na_2O and K_2O to exist in stoichiometric ratios with respect to each other. The same is true elsewhere, notably in the Christiania region, where Brögger[3] connects it with the tendency of the alkalis to such ratios in nepheline and soda-orthoclase. Such ratios, however, in igneous rocks are by no means general.

When we examine this ratio in the various rocks we see that it is characteristic of certain rock groups. In the granite, the quartz-syenite-porphyry and the quartz-syenites it is quite constant, varying only from 1.09 to 1.17. In the aplite dike it is a little higher, about 1.5. In the keratophyre and rhyolite it is still higher, 1.40 and 2.20. As we go toward the basic end the ratio increases, being 1.7 and 2.1 in the pulaskites, 2.2, 2.5, and 3.6 in the sölvsbergites and biotite-tinguaite, and 3.0 in the foyaites. In the basic rocks, from diorite down, the ratios are constantly high, varying from 2.6 to 6.6, and is also high, 6, in the analcite-tinguaite.

[1] PENFIELD and FORBES: Am. Jour. Sci. (IV), I, 129, 1896.

[2] H. S. WASHINGTON: Am. Jour. Sci. (IV), VI, 179, 1898.

[3] BRÖGGER: Eruptivgesteine der Kristianiagebietes. I, 165, 1894, and III, 249, 1897.

It will be seen that in what are obviously connected series of ›cks there is a regular variation in one direction, an increase ›ward the basic end. The most striking instance is the paisanite-.nguaite series, in which the ratios are 1.23, 2.17, 2.47, 3.62, and .97. Also in the pulaskite-foyaite-essexite series, where the atios are 1.71, 2.09, 3.00, 2.98, and 3.64. The granite, quartz-yenites, diorites, and gabbros show the relation less well, hough even here the ratio is markedly higher in the basic 1embers.

These observations leave no doubt of the fact that in Essex ounty Na_2O increases relatively to K_2O as SiO_2 decreases. 'his agrees with the Christiania region, where Brögger[1] shows nat in the grorudite-tinguaite series the same holds good. In oth cases the effect is due chiefly to increase in Na_2O relatively › SiO_2, K_2O remaining comparatively stationary. The line iving the ratio of $Na_2O : SiO_2$ will show this for Essex county. uch a variation is not universal, as in other regions exactly the ontrary obtains,[2] the K_2O increasing as SiO_2 decreases.

It is evident, therefore, that Na_2O and K_2O differentiate 'ith respect to each other, a fact to which Pirsson has already alled attention.[3] This is of theoretical interest since it indicates 1at, notwithstanding their general similarity, there is a difference etween the two alkalis in their functions in igneous rocks, a ıbject which space does not permit of being treated here.

$\frac{FeO}{Fe_2O_3}$. The variations in this ratio are far greater than in 1e preceding, ranging from 0.37 to 16.0, but examination reveals ertain regularities. It is very high in the granite, aplite, uartz-syenite, and porphyry, and in all the basic rocks. It will lso be observed that it is higher in the dike rocks than in their orresponding plutonic forms. It is lower in the paisanite and ›lvsbergites, still lower in the pulaskites and foyaites, as well as

[1] BRÖGGER: *op. cit.*, Vol. III, p. 249, note 1, 1897.

[2] PIRSSON: Bull. 139 U. S. Geol. Surv., p. 138, note 5, 1896. HARKER: Geol. ag., Vol. IX, 203, 1892.

[3] PIRSSON: Bull. 139 U. S. Geol. Surv., p. 138, 1896.

in the rhyolite and keratophyre, and lowest of all in the tinguaites.

It is evident, granting that these relations are not fortuitous, which the number of analyses seems to preclude, that this ratio does not vary with the SiO_2, but seems to be dependent here on the general character of the magma from which the rocks solidified. Grouping these roughly into two classes according to their general characters we may say that the ratio is high in the granito-dioritic group and low in the foyaitic.

It is, it must be confessed, somewhat surprising to find such a connection between the ratio of the two iron oxides and the petrographical character of the rocks. Is it indeed the fact that there is such a difference in behavior between the two oxides? Do they really differentiate with respect to each other, or is the relation only apparent and due to other causes, such as possible oxidation of the ferrous iron in the foyaitic rocks? In the flow rocks the ratio is low and it seems possible that their solidification at the surface may have induced oxidation. But all the other rocks are abyssal or hypabyssal, so that such an action would seem to be excluded, or at least equally effective in each. We have also seen that the granito-dioritic dikes show a uniformly higher ratio than their plutonic analogues. On the whole we seem driven, as far as the data at hand allow us to decide, to the conclusion that the two oxides differentiate with respect to each other and that their ratio is in some way connected with the composition of the magma.

In connection with this ratio we may note the interesting case of Nos. XV and XIV, the tinguaite and sölvsbergite, whose composition is very similar, the total iron oxides being about the same. In the tinguaite the high Fe_2O_3 (ratio 0.52) has conditioned the formation of aegirite, while in the sölvsbergite the high FeO (ratio 3.31) has conditioned the formation of glaucophane-riebeckite as the colored mineral.

$\frac{Na_2O+K_2O}{SiO_2}$ This ratio has been recently employed by Iddings[1] in the investigation of the relationships of rocks. Here

[1] IDDINGS: JOUR. GEOL., Vol. III, 956, 1895, Vol. VI, 96, 189, Vol. VI, 219, 1898.

it corresponds in a general way with the grouping already used. In the acid rocks, from granite to akerite, the ratio is low and fairly constant, varying only from .088 to .121. In the foyaitic rocks from glaucophane-sölvsbergite to analcite-tinguaite, it is much higher and also fairly constant, from .156 to .228. In the basic rocks the ratio is again low, the essexite alone showing the high ratio of .166, analogous to that of the foyaites, as was to be expected. The ratio of the hornblende-gabbro (.112) is also in accord with its transitional character between the diorites and essexite.

A large number of other ratios have been examined, but without any very significant results. The only one worth mention is that of $Al_2O_3+Fe_2O_3:CaO+Na_2O+K_2O$. In the more acid rocks, from pulaskite up, this approximates closely to unity, but below this there are some other wide variations, the sesquioxides being deficient, except in the foyaites.

The rock series.—Without going further into details, we may divide the rocks of Essex county into the following series as defined by Brögger.[1]

The first may be called the *granito-dioritic*, and embraces the granites, quartz-syenites, quartz-diorites, diorites (which are partly monzonitic), and gabbro. These are characterized mineralogically by the presence of microperthite (albite and orthoclase) in the more acid members and plagioclase with some alkali-feldspar in the basic, and by iron-micas (in the more acid) and green and brown hornblendes and pyroxenes. Chemically they show comparatively low ratios of Na_2O to K_2O and Na_2O+K_2O to SiO_2, and high ratios of FeO to Fe_2O_3.

To this is related a series of dike rocks, including the aplites and microgranites, quartz-syenite-porphyry, and, at the basic end, probably a part of the diabases. These dike rocks possess chemical and mineralogical characters similar to those of the preceding series.

The next prominent series is the *foyaitic*, embracing the pulaskite, litchfieldite, and essexite, and characterized by the

[1] BRÖGGER: Eruptivgest. d. Kristianiageb. Vol. I, p. 169, 1894.

abundance of the albite molecule, lack of lime-soda feldspars, and presence of nepheline, aegirite, and blue glaucophane-riebeckite or brown barkevikite. These rocks show high Na_2O : K_2O : and $Na_2O + K_2O : SiO_2$ ratios and low $FeO : Fe_2O_3$.

Related to this series are the dikes of the sölvsbergite-tinguaite series, and of paisanite, also possibly the camptonitic dikes. These show chemical and mineralogical characters analogous to those of the foyaitic series, but vary far more in composition.

These four series, which are very well defined, include nearly all the rocks examined. Among the exceptions the hornblende-gabbro occupies, as we have seen, a position intermediate between the diorites and essexites, and may be reasonably regarded as a transitional and connecting form. The flow rocks are abnormal. In certain respects they seem to be allied with the granito-dioritic rocks, while other characters suggest affinities with the foyaites. The question is a difficult one to decide. The orbicular syenites, which are present in very small amount, are almost certainly related to the granito-dioritic series, though lack of an analysis leaves the question uncertain. By its mineralogical characters and by its ratios the Quincy granite belongs to a foyaitic series, forming the most acid member of it, and corresponding to the paisanites among the dike rocks. As it belongs to the Blue Hills Complex, quite outside our region, it will not be discussed further.

Relations of the various types.—As a preliminary to the determination of the genetic connection of the various rocks, it will be well to obtain some idea of the relative amounts of the different types represented. For obvious reasons it is, of course, not possible to do this with certainty or accuracy. If we assume that the areas shown on the geological map are dependent on the relative volumes (which may or may not be the case) we shall get an estimate, which, though very far from being accurate or wholly satisfactory, may be considered provisionally to express the relation in a general way, and which will probably be sufficient for our present purpose.

An examination of Mr. Sears' map, together with a consideration of my own observations, permits me to estimate, ***in a very rough way***, the relative percentage areas given in the following table, in which are also given the relative volumes, reduced to percentages, calculated from these data. This estimate, it must be observed, includes only the main area of igneous rocks, excluding the area of sedimentaries and gneisses, etc., which covers the western part of the county, as well as the quartz-diorite area near Newburyport, since the northerly extension and connections of this are unknown to me.

Rock	Area, %	Volume, %
Granite	30	37.2
Quartz-syenites	24	26.4
Diorites	28	33.4
Foyaites	2	0.6
Essexite	1	0.2
Gabbro	1	0.2
Acid Dikes	1	0.2
Basic Dikes[1]	3	1.2
Rhyolite[2]	10	0.6

It will be seen that the granites and quartz-syenites constitute nearly two thirds of the total, the diorites[3] one third, while all the others make up only three per cent. This result is of special interest since this region is generally regarded by petrographers as essentially one of nepheline-syenites. They occur, it is true, but form only a small, though important, part of the complex.

[1] Shaler (*op. cit.*, p. 583) estimates the area of the dikes of Cape Ann at 5 to 10 per cent. As dikes are apparently less abundant elsewhere I have reduced this considerably, especially as my observations lead me to think it too high.

[2] As these are flow rocks their depth will be small compared to their area, and I have therefore estimated their volume at only a tenth of that calculated on the basis of the other rocks.

[3] I have recently received from Mr. Sears a large and representative collection of the diorites of the main western Ipswich-Danvers area. Although time is lacking for proper microscopical and chemical study, they are evidently quite basic, and to all appearance approximate very closely to those already described, chemically and mineralogically.

Assuming that the figures given in the table above are roughly true (which is quite hypothetical), it will be of interest to calculate the composition of the magma as a whole. The results of this calculation, which are admittedly crude and of little reliability on account of the character of the data employed, are as follows:

SiO_2,	TiO_2,	Al_2O_3,	Fe_2O_3,	FeO,	MgO,	CaO,	Na_2O,	K_2O,	H_2O, etc.
65.3	1.0	14.5	1.2	4.6	1.7	3.6	3.7	4.0	0.4=100.

The result corresponds in general with the idea of the magma derived from examination of the analyses, though it is perhaps somewhat higher in MgO and CaO, and hence more monzonitic, than we might have expected. Of the rocks analyzed it approaches most closely to that of the akerite (No. X), but it shows less SiO_2 and alkalies, and more MgO and CaO than this. A rock of this composition would probably be found among the more basic akerites or more acid diorites.

Leaving this aside for the present it will be evident that the main course of differentiation (assuming that such has taken place), has been to form a large series of granites, quartz-syenites, and diorites, which pass into one another more or less gradually through transition forms. Among these there is a quite gradual gradation of the oxides, as will be seen on reference to the table of analyses. A rather peculiar feature is the increase of Al_2O_3 in the basic members, which is quite unusual. Parallel series from other regions analogous to this might be mentioned, but it seems scarcely worth while to do so.

The series of granito-dioritic dikes, which correspond so closely both mineralogically and chemically to the granolites, must be classed as aschistic[1], *i. e.*, which are not separate differentiation forms of their magmas, but only dike forms of the partial magmas which solidified elsewhere as granolites.

The foyaitic series presents a somewhat different problem. These rocks are evidently connected genetically with the main

[1] BRÖGGER: *op. cit.*, Vol. I, p. 125. I am in some uncertainty in thus rendering into English BRÖGGER's words *aschist* and *diaschist*. The termination -ic would seem to be better than -ous or -ose, which latter is already in use in schistose, denoting structure.

ries, both on geological grounds and petrographical, such as
ie transition forms between the essexite and diorites. They
present, however, a distinctly different magma; one not only
iore basic, but richer in Na_2O and Al_2O_3 and poorer in CaO,
IgO, and FeO. They are also notable for the fact that consider-
ig their very small amount they are relatively more differen-
ated than the main magma. This is in accordance with obser-
ations on nepheline-syenite regions elsewhere, which, it is well
nown, carry not only a very great number and variety of rare
omponent minerals, but also show a comparatively large num-
er of rock varieties.

Since it has been shown that in the granito-dioritic series
Na_2O tends to increase relatively to K_2O as SiO_2 decreases, and
t the same time as it increases inversely as SiO_2, it follows that
n the course of a differentiation of such a magma there should
e an enrichment of Na_2O at the basic end. The rocks of the
oyaitic series may then be held to represent the further differ-
ntiation products of such a basic, soda-rich portion of the main
iagma, this further differentiation taking place in accordance
ith the tendency of magmas rich in soda to differentiate, while
i the more acid portions the relations would remain more simple.
his explanation is essentially that of Pirsson[1] to account for
he phonolitic dikes of the Judith Mountains.

Lack of space forbids the full discussion of the foyaitic dike
ocks, comparing them with the main types as Brögger has done,
ut the evidence goes to show that the paisanite, sölvsbergites,
nd tinguaites are probably to be regarded as diaschistic dikes,
. e., further differentiation products of the foyaitic magma, and
iot simply dike forms of this. This is analogous to the Chris-
iania region, where Brögger[2] has shown that the dikes of the
grorudite-tinguaite series are diaschistic.

The differentiation probably laccolithic.—We have now to examine
the question as to where the differentiation of the Essex county
magma took place. Are the rocks, as we see them, due to

[1] PIRSSON: Eighteenth Ann. Rep. U. S. Geol. Surv., p. 573, 1898.

[2] BRÖGGER: *op. cit.*, p. 127 ff.

successive injections of liquid magmas and the differentiates[1] of a more deeply seated magma, only part of which was released from the reservoir, or are they the differentiates *in situ* of a body of magma which was injected in a more or less homogeneous condition from below? Is the differentiation, in other words, "deep magmatic," or "laccolithic?"[2] Very thorough and careful field study is necessary to decide this question, study which it has not been possible for me to undertake. At the same time, certain considerations seem to point to the conclusion that the differentiation at Essex county was laccolithic, and that the complex may possibly be regarded as a laccolith. I can only point out very briefly the facts on which this conclusion rests, leaving the further study and settlement of the question to others.

Comparatively very few differentiated laccolithic masses have been studied, but those which we know best show a basic border and more acid interior, with, in some cases, an intermediate zone of medium composition. Prominent examples of these are Brandberget, in Gran;[3] Carrock Fell[4] in England, and the especially beautiful and instructive ones described by Weed and Pirsson, notably, Square Butte,[5] Yogo Peak,[6] and Bear Paw Peak[7] in Montana.

On looking at the geological map of Essex county,[8] it is seen that the main granite area is to the east, extending in large patches from Cape Ann westward, and ending in this

[1] I use this term as synonymous with and more convenient than "differentiation product." It is formed analogously to the word *solute.*

[2] BROGGER: Quart. Jour. Geol. Soc., Vol. L, p. 29 ff., 1894, and Erupt. gest. d. Christ. geb., Vol I, p. 153, 1894.

[3] BROGGER: Quart. Jour. Geol. Soc., Vol. L, p. 31, 1894.

[4] HARKER: Quart. Jour. Geol. Soc., Vol. L, p. 311, 1894, and Vol. LI, p. 125, 1895.

[5] WEED and PIRSSON: Bull. Geol. Soc. Am., Vol. VI, p. 389, 1895.

[6] WEED and PIRSSON: Am. Jour. Sci. Vol. L, p. 467, 1895.

[7] WEED and PIRSSON: Amer. Jour. Sci., Vol. I, p. 351, 1896.

[8] The map here given is copied from the revised one of Mr. Sears, some omissions being made on account of the greatly reduced scale. An attempt has been made to show approximately the small foyaite area along the Beverly Shore.

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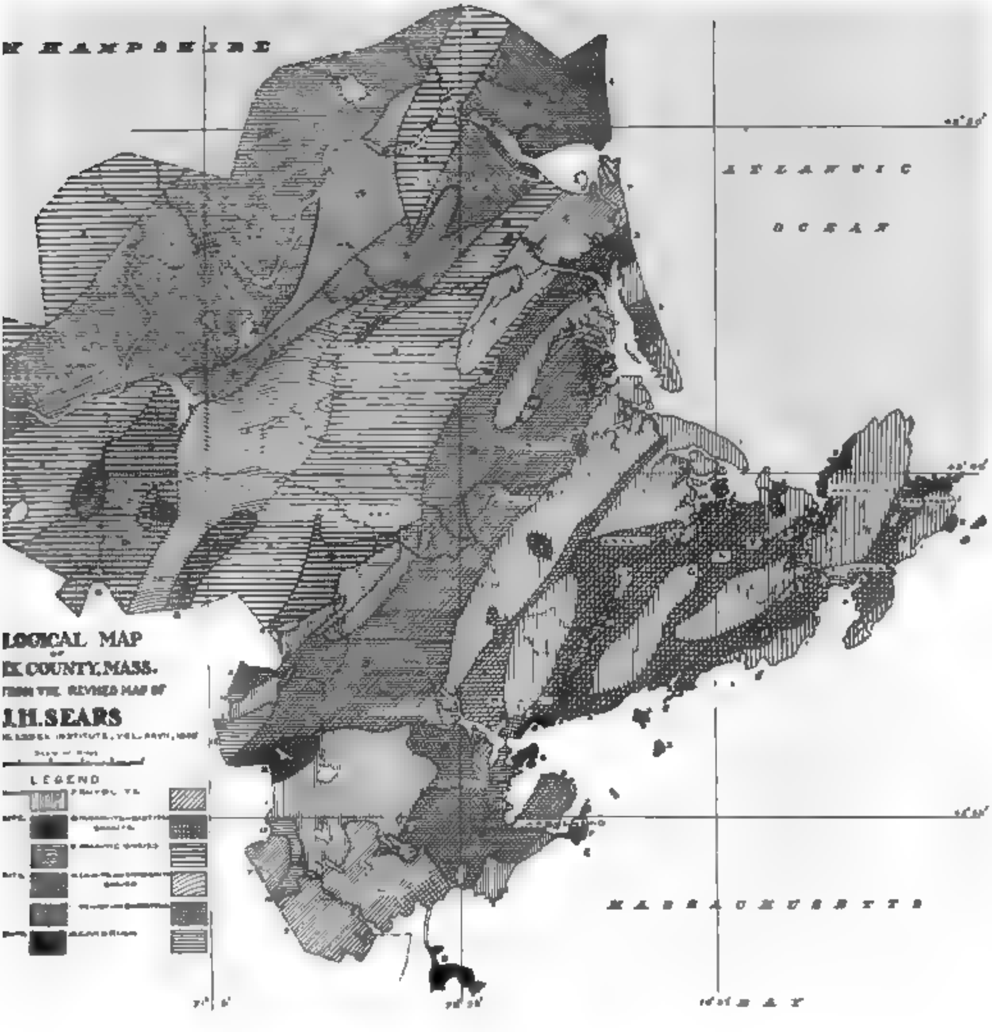
Plate VI



direction in a broad zone which runs north-northeast from Beverly to Ipswich. Interspersed with the granite and surrounding some of the smaller areas is quartz-syenite, which is not met with west of the granitic zone, except in two small patches. West of the granite area, and forming also a broad zone running north-northeast, is the main area of diorite, which curves around to the south, forming the Salem area, and is also met with as strips and tongues in the granite areas. West and northwest of the diorite are found sedimentary and metamorphic rocks, of which something will be said later. The small area of foyaitic rocks lies near Salem, south of the western parts of the granite and quartz-syenite areas. The gabbro is only met with at the extreme south, on the small promontory of Nahant with patches of metamorphosed Cambrian sedimentaries. To the south near Lynn, and north near Newburyport, are areas of rhyolite, a small patch of which is also found at Marblehead Neck, southeast of Salem.

There is then a rather regular arrangement, the acid rocks being to the east and the basic diorites surrounding them to west and south, lying on the outside next to the nonigneous rocks. This is suggestive of the arrangement of the rocks in the ordinary type of differentiated laccolith.

In the next place, according to Mr. Sears' map and his description of the sedimentary rocks,[1] we find that the dips of the sedimentaries and metamorphosed rocks, which form the western part of the county, are in general to the northwest or north-northwest, *i. e.*, away from the igneous area. This is also suggestive of a laccolithic mass, and the few small areas of sedimentaries metamorphosed by contact with the igneous rock, which are met with here and there through the igneous areas, may be considered to be remnants of the original cover. In fact, Mr. Sears, himself, indicates the conclusion that the mass is an anticlinal laccolith, when he says:[2] "The position of these two metamorphosed crystalline sedimentary beds signifies that

[1] SEARS: Bull. Essex Inst., Vol. XXII, p. 1, 1890.

[2] SEARS: Bull. Essex Inst., Vol. XXIII, p. 15, 1891.

hey are remnants of an anticlinal fold of the Cambrian sediients, perhaps produced by the intrusion of the eruptive granite iagma from beneath them."[1]

A further fact, which is in favor of laccolithic differentiation, s the radical difference of opinion of the two observers, Wadsvorth and Sears, who are best acquainted with the region, as to he order of succession of the igneous rocks. Leaving the likes out of consideration, and adopting the nomenclature of his paper, Wadsworth[2] gives it as follows, beginning with the arliest: gabbro and diorite, quartz-syenite, nepheline-syenite, ranite, and rhyolite. Sears,[3] on the other hand, gives granite, uartz-diorite, essexite, diorite, nepheline-syenite, and quartz-syeite, gabbro, rhyolite. This argument is not conclusive, since the ifferences of opinion are perhaps explicable on the ground of ack of good exposures, etc., but in the case of two good bservers, who made a careful study of the region, they are sugestive of the fact that there is no "order of succession" in the sual sense of the term, and which we would not expect to find n the case of a differentiating laccolithic mass of magma.

Lastly, it may be mentioned that the rocks are just what we ight expect to find as the differentiates of a magma, such as is was, when laccolithically differentiated. The transition types hich exist between the various members, and the "schlieren," uch as those in the diorite of Marblehead, are also in favor of is hypothesis, as is also the greater abundance of dikes in the ranites as compared with the diorites, since it seems reasonable o suppose that many cracks formed from below would penetrate he granite, and not the overlying diorite zone.

Several objections may readily be brought against this hypothsis, among which may be mentioned, the asymmetric character f the complex and the absence of quartz-syenite between the ranite and diorite, where we should expect to find it. The first

[1] A similar structure is apparently suggested by HOBBS (Amer. Geol., Vol. XII, p. 110, 1899) for the area about Waltham, southwest of our region.

[2] WADSWORTH: Geol. Mag., p. 209, 1885.

[3] SEARS: Bull. Essex Inst., Vol. XXVII, p. 109, 1895.

objection may be met with the fact that such asymmetric laccoliths are known, and are to be looked for in certain conditions of the surrounding strata.[1] Further, the presence of the coastal fault line and the Atlantic Ocean to the east is a sufficient explanation for the disappearance of a large part of the mass on this side.[2] The irregularity of the quartz-syenite is a more serious objection, and is, perhaps, best explained by the admitted fact that the laccolith must have been of a decidedly irregular shape, owing to the conformation of the strata into which it was intruded. It is possible, also, that considerable faulting may have taken place. The microscope shows that most of the rocks have been subjected to pressure, such as would be consequent on crustal movements. It must be noted that I am here using the term laccolith in a broad sense, as Cross and Pirsson have done to include "all thick lenticular (in this case elongated) masses which have domed up the strata, and have over the greater part of their area a roof of sediments"[3] (here largely disappeared through erosion, glacial, and otherwise). The actual presence of this last feature is not essential to the idea, since any cover may be removed by erosion without affecting the original character of the mass.

It may also be remarked that, as far as can be seen, the course of differentiation would be the same whether, as in a true laccolith, the intruded magma bulged up the overlying strata, or entered an arch space formed otherwise.[4] From the petrological standpoint the mechanics of the process are of secondary importance. The chief point of my suggestion is that the differentiation was laccolithic and of a mass *in situ*, and not deep magmatic, and the rocks the results of successive intrusions. In the one

[1] W. CROSS: Fourteenth Ann. Rep. U. S. G. S., p. 236 ff, 1895. PIRSSON: Eighteenth Ann. Rep. U. S. G. S., pp. 555, 581, 1898.

[2] MR. SEARS (Bull. Essex Inst., Vol. XXII, p. 16, 1890) notes the occurrence of Cambrian limestone at Jeffrey's Ledge, in the Atlantic Ocean, about twenty miles east of Cape Ann.

[3] PIRSSON: *loc. cit.*, p. 581.

[4] For an example of the latter cf. WATTS: Rep. Brit. Assoc. 1886, p. 670 and Proc. Geol. Assoc., 1894, p. 341.

se the rocks are all genetically connected, in the other posbly not.

Conclusion and summary.—My view, then, of the structure of e complex and genetic relationships of the rocks of Essex unty is as follows. The igneous area represents possibly a ction through an elongated, irregular, anticlinal, laccolithic ass, with a N. N. E.—S. S. W. trend, intruded into already disrbed Cambrian strata. The plutonic igneous rocks represent e products of a laccolithic differentiation in this magma, and t successive intrusions. The magma was rather acid, rich in kalies and ferrous iron, and possibly did not differ materially om the calculated composition given on page 472. This course differentiation produced primarily and most abundantly the anites, quartz-syenites, and diorites, with their corresponding chistic dikes as *Nachschube.* A secondary local differentiation the more basic differentiates of this process gave rise to the yaites and essexites, while the rocks of the paisanite-tinguaite ries are probably diaschistic dike forms of these. At a much ter period, after erosion had removed much of the covering of e granolites, the rhyolites were erupted, from some unknown nts. Lastly, here, as so often elsewhere, the diabases were jected into the much cracked complex.

Comparison with other regions.—So much space has been voted to the previous discussion that a few words must suffice r this topic. From the references to the Christiania region roughout the paper and comparison of the analyses, the general rrespondence between the two is evident. There are differces in details, such as the more acid and somewhat less sodah character of the Essex county rocks, abundance of diorites re and of laurvikites and laurdalites in Norway, etc. But it may said that the general course of differentiation was essentially uch the same in both, a fact which supports the theory that e variations of rocks are largely subject to physico-chemical ws, and are not fortuitous and due to the composition of the rrounding rocks and other external circumstances, as Johnstonavis and Becker would have us believe.

A comparison could also be instituted with the other igneous rocks of the New England region, going to show that great similarities exist. But our knowledge of most of the other igneous regions of New England and Canada is so scanty that the time does not seem ripe for this. It will be sufficient to note that some of the rocks of Essex county show great analogies with, for instance, those of Litchfield, Maine, and Red Hill and Mt. Ascutney, New Hampshire. Farther west, in the Adirondacks and near Montreal, the character of the magma seems to be different, as has been pointed out recently by Cushing,[1] though there are many resemblances.

HENRY S. WASHINGTON.

[1] H. P. CUSHING: Bull, Geol. Soc. Amer., Vol. X, p. 191, 1899.

TABLE I.

	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
....	77.61	77.14	76.49	73.93	71.40	70.64	68.88	69.36	67.35	66.60	64.28	63.71
....	0.25	0.29	trace	0.18	.....	0.90	0.19	trace	0.60	0.76	0.50	trace
...	.....	.....	.....	.....	.....	.....	.. ..	.....	.....	.....	.....	.....
....	11.94	12.24	11.89	12.29	14.76	15.34	14.77	16.58	15.05	15.05	15.97	18.30
....	0.55	0.29	1.16	2.91	1.68	1.83	0.64	0.90	1.23	1.07	2.91	2.08
....	0.87	1.04	1.56	1.55	0.72	1.10	4.64	3.24	4.76	4.42	3.18	2.52
....	trace	trace	trace	trace	trace	trace	trace	trace	0.05	trace	trace	trace
....	trace	0.06	trace	0.04	0.55	0.52	0.37	0.45	0.03	0.36	0.03	0.09
.....	0.31	0.35	0.14	0.31	0.10	1.24	1.74	1.85	0.55	2.21	0.85	1.18
.....	.....	.....	.....	none	.....	.....	.....	.....	.....	none	none	.....
.....	3.80	4.64	4.03	4.66	4.79	5.23	3.83	3.97	4.42	4.03	7.28	6.39
.....	4.98	4.47	5.00	4.63	5.16	3.55	4.97	5.27	6.08	5.42	5.07	6.21
.....	trace	trace	0.12	.....	.....	0.14	0.06	0.18	0.16	.....	.....	0.09
.....	0.23	0.14	0.38	0.41	1.46	0.38	0.24	0.17	0.17	0.41	0.20	0.17
.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.08	.....
	100.54	100.66	100.77	100.91	100.62	100.87	100.33	100.97	100.45	100.33	100.33	100.74
......	2.618		2.650	2.642		2.632	2.696		2.690	2.612	2.703	2.686
......	18°C.		13°C.	22°C.		12.5°C.	12°C.		17°C.	17°C.	22°C.	12°C.

TABLE I — *Continued.*

	XIII	XIV	XV	XVI	XVII	XVIII	XIX	XX	XXI	XXII	XXIII	XXIV
....	63.09	61.05	60.05	59.31	58.77	56.75	51.82	47.12	46.99	46.59	45.32	43.73
.....	0.45	0.34	0.11	0.32	0.31	0.30	2.15	3.27	2.92	1.41	1.94	4.23
......	0.06	.....	.....	.....	0.11	.....	.....	.....	.....	.....	.....	....
.....	18.50	18.81	19.97	22.50	22.64	20.69	17.06	14.43	17.94	17.55	18.99	20.17
......	2.90	2.02	4.32	1.93	1.54	3.52	1.97	3.33	2.56	1.68	3.78	4.32
....	1.36	3.06	1.04	1.40	1.04	0.59	8.60	11.71	7.56	10.46	9.78	6.93
....	trace	trace	0.79	trace	trace	trace	trace	.....	.....	.....	.....	.....
......	0.16	0.42	0.23	0.17	0.19	0.11	4.87	6.05	3.22	7.76	4.68	3.91
....	1.00	1.30	0.91	0.46	0.74	0.37	8.59	9.63	7.85	10.64	9.19	10.99
......	.....	none	.....	.....	none	none	.....	.....	none	.....	.....	.....
....	7.25	6.56	7.69	7.98	9.62	11.45	3.44	2.58	6.35	3.31	3.78	2.42
....	5.23	6.02	3.24	4.08	4.89	2.90	1.77	1.11	2.62	0.72	2.12	1.45
......	0.21	.....	0.15	0.15	0.07	0.04	0.11	0.28	.....	0.10	0.09	0.08
it).....	0.62	0.78	1.26	1.12	0.90	3.18	0.20	0.34	0.65	0.07	0.31	1.02
....	.....	.....	Cl=0.28	.....	.....	Cl=0.28	.....	.....	0.94	.....	.....	0.15
	100.83	100.36	100.04	99.42	100.82	100.18	100.58	99.85	99.60	100.29	99.98	99.40
....		2.655	2.708	2.599	2.596	2.474		3.072	2.919	3.047	2.975	3.058
.....		12°C.	....	12 C.	11 C.	22 C.		12 C.	12 C.	11 C.	11 C.	11°C.

I. Granite. Rockport.
II. Aplite (mean). Bass Rocks.
III. Paisanite. Magnolia.
IV. Granite. Quincy. (Blue Hills.)
V. Keratophyr. Marblehead Neck.
VI. Rhyolite. Marblehead Neck.
VII. Quartz-syenite-porphyry. Squam Light.
VIII. Nordmarkite. Wolf Hill.
IX. Enclosure in Granite. Rockport.
X. Akerite. Gloucester.
XI. Sölvsbergite. Andrew's Point.
XII. Pulaskite. Salem Neck.
XIII. Pulaskite. Salem Neck.
XIV. Sölvsbergite. Coney Island.
XV. Tinguaite. Gale's Point. (Eakle.)
XVI. Foyaite. Great Haste Island.
XVII. Foyaite. Salem Neck.
XVIII. Tinguaite. Pickard's Point.
XIX. Diorite. Marblehead.
XX. Diabase. Rockport.
XXI. Essexite. Salem Neck.
XXII. "Camptonite." Salem Neck.
XXIII. Hornblende Gabbro. Salem Neck.
XXIV. Gabbro. Nahant.

TABLE II.

	Ia	IIa	IIIa	IVa	Va	VIa	VIIa	VIIIa	IXa	Xa	XIa
SiO_2	1.294	1.286	1.275	1.232	1.190	1.177	1.148	1.139	1.123	1.110	1.071
Al_2O_3	.117	.120	.117	.120	.145	.150	.145	.163	.148	.148	.156
Fe_2O_3	.003	.001	.007	.018	.011	.011	.004	.006	.008	.007	.018
FeO	.012	.014	.022	.022	.010	.014	.064	.045	.066	.061	.044
MgO	....	.002	....	.001	.014	.013	.009	.011	.001	.009	.001
CaO	.005	.006	.002	.006	.002	.022	.031	.033	.010	.039	.015
Na_2O	.061	.075	.065	.075	.077	.084	.062	.064	.071	.065	.117
K_2O	.053	.048	.053	.049	.055	.038	.053	.056	.065	.058	.054
$\frac{Na_2O}{K_2O}$	1.15	1.56	1.23	1.53	1.40	2.21	1.17	1.14	1.09	1.12	2.17
$\frac{FeO}{Fe_2O_3}$	4.00	14.00	3.14	1.22	0.91	1.28	16.00	7.50	8.25	8.71	2.44
$\frac{Na_2O+K_2O}{SiO_2}$	.088	.096	.092	.101	.111	.104	.100	.105	.121	.111	.156
$\frac{Na_2O}{SiO_2}$	.047	.059	.051	.061	.065	.071	.054	.057	.063	.059	.110

TABLE II.—*Continued.*

	XIIIa	XIVa	XVa	XVIa	XVIIa	XVIIIa	XIXa	XXa	XXIa	XXIIa	XXIIIa
SiO_2	1.052	1.018	1.001	0.989	0.980	0.946	0.864	0.785	0.783	0.777	0.766
Al_2O_3	.181	.183	.196	.221	.222	.203	.167	.142	.176	.172	.186
Fe_2O_3	.018	.013	.027	.012	.010	.022	.012	.021	.016	.011	.023
FeO	.014	.043	.014	.019	.014	.008	.120	.163	.105	.145	.136
MgO	.004	.011	.005	.004	.005	.003	.122	.151	.080	.194	.117
CaO	.018	.023	.016	.008	.013	.007	.153	.172	.140	.190	.164
Na_2O	.117	.158	.123	.129	.155	.185	.056	.042	.102	.053	.061
K_2O	.056	.064	.034	.043	.052	.031	.019	.012	.029	.008	.023
$\frac{Na_2O}{K_2O}$	2.09	2.47	3.62	3.00	2.98	5.97	2.95	3.50	3.64	6.63	2.65
$\frac{FeO}{Fe_2O_3}$	0.78	3.31	0.52	1.58	1.40	0.37	10.00	7.74	6.57	13.19	5.67
$\frac{Na_2O+K_2O}{SiO_2}$	.164	.218	.157	.174	.211	.228	.086	.069	.166	.078	.112
$\frac{Na_2O}{SiO_2}$	.111	.155	.123	.130	.157	.195	.065	.053	.130	.068	.080

A PECULIAR DEVONIAN DEPOSIT IN NORTHEASTERN ILLINOIS

THE village of Elmhurst is in the eastern edge of DuPage county, Illinois, on the Chicago and Northwestern Railway, fifteen miles west of the Wells Street Station in Chicago. On the north side of the railway track, about one mile west of the station, are the Elmhurst quarries. The rock quarried, which is the buff or bluish Niagara dolomite of northeastern Illinois and Wisconsin, has been excavated to a depth of about thirty feet.

At this locality the limestone is much fractured by two sets of gentle folds whose axes have a general north-west south-east and north-east south-west direction, joint cracks being well developed. Some of these cracks are several inches in width, and are in general filled with a black or blue clay. At one point, in the south-east face of the quarry, about eighteen feet below the glaciated surface of the rock, one of these joints is somewhat enlarged to form a narrow triangular opening about six inches in width at the base and about sixteen inches in height. This opening, instead of being filled with clay, as are all the other larger joints in the quarry, is filled with a breccia composed of angular fragments of the adjacent limestone, imbedded in a dark brown arenaceous matrix. This matrix is abundantly fossiliferous, containing immense numbers of fish teeth, and a smaller number of *Lingula* shells and other brachiopods, which indicate its Devonian age.

The situation of this most peculiar occurrence of Devonian fossils, deeply buried in the Niagara limestone, is shown in the accompanying illustrations. Figure 1 is a near view, showing the Devonian material filling the triangular opening to the left of the hammer. Figure 2 was taken from a greater distance, in order to show the position of the opening in the face of the

quarry about eighteen feet below the surface. The species of fossils recognized are as follows:

Fish teeth.
Ptyctodus calceolus N and W.
Diplodus priscus Eastman n. sp.
Diplodus striatus Eastman n. sp.

Brachiopods.
Lingula ligea H.?
Orbiculoidea newberryi H.?
Ambocoelia umbonata Con.

The most abundant species is *Ptyctodus calceolus*, whose tritors are present literally by the hundreds. This species is characteristic of the middle and upper Devonian faunas of the inte-

FIG. 1.

r of North America. It has been recorded[1] from Canada, lwaukee, Wis., western Illinois, Missouri, Iowa, and Manitoba. e Elmhurst specimens are generally smaller than those usually nd in Iowa and other localities, but there seems to be no essen- difference in form. The remaining fish teeth are two new

FIG. 2.

:cies of the genus *Diplodus* which have been described by Dr. R. Eastman.

Among the brachiopods, the one identified as *Lingula ligea* is : most abundant. It was originally described from the Ham- ɔn in New York, but it also occurs in the Upper Devonian of : same state and has been recorded from the Devonian in

[1] Iowa Geol. Surv., 1898, Vol. VII, p. 114; Am. Nat., 1898, Vol. XXXII, p. 476.

Nevada. *Ambocoelia umbonata*, a single individual of which has been observed, is a common Hamilton species in New York, although a variety of the same species also occurs in the Upper Devonian. *Orbiculoidea newberryi*, also represented by a single observed specimen, has been recognized only in the Waverly series of Ohio, near the base of the Carboniferous.

The presence of *Ptyctodus* is certainly indicative of the Devonian age of the fauna, but *Diplodus* has previously been recognized only in Carboniferous strata, and the presence of two species of this genus with the Waverly species of *Orbiculoidea* would seem to indicate a very late Devonian age.

The presence of a fauna of this age in such a situation, is of extreme interest. The nearest point where Devonian strata form the surface rock is probably in northwestern Indiana, but that region is so heavily drift covered, and has been so little studied, that the exact distance from Elmhurst to the nearest Devonian strata in that direction cannot be determined with accuracy. Furthermore, the Devonian strata known in northern Indiana, are the black shales, and do not contain a fauna with *Ptyctodus*. The nearest actual outcrop of Devonian is at Milwaukee, Wis., eighty miles north of Elmhurst; and the nearest outcrop to the west is near Rock Island, Ill., one hundred and thirty miles away. At both of these localities *Ptyctodus calceolus* occurs, but the strata are believed to be somewhat older than the material from Elmhurst.

The presence of this Upper Devonian fauna at Elmhurst, buried as it is deep down in the Niagara limestone, indicates with certainty that during the greater part of Devonian time, the region now known as northern Illinois was above sea level. It was part of what was probably a large land surface, stretching from the Wisconsin land on the north to the Ozark land of Missouri on the south. The waters which collected upon this land surface in part percolated through the underlying rock strata and by solution increased the size of many joint cracks. At a later period, near the close of the Devonian, when the sea again occupied the region, sand was sifted down into these open joints, and with

the teeth of fishes which inhabited the sea thereabout. It is rhaps possible that the opening which has in recent time been covered at Elmhurst, was during this late Devonian time large ough for the entrance of some of these fishes, and that they ught this opening for shelter, much as fishes at the present time ter similar openings.

The manner of communication between this opening and the rface is not clearly shown in the field, but arenaceous material

Fig. 3.

th fragments of fish teeth is seen clinging to the quarry face the left of and above the opening. This material may be ther indistinctly seen in Fig. 1, being represented by the dark otches upon the lighter colored rock in the position indicated. iis rock face is one side of a joint whose opposite side has been moved, through which there may have been communication :tween the buried opening and the sea bottom above. The

Devonian material is not continuous for any great distance back from the quarry face, as will be seen in Fig. 3, this figure being a view taken nearly at right angles to that shown in Fig. 1, after the rock to the right of the opening against which the hammer leans in Fig. 1, has been removed. The Devonian material in the figure is the darker rock above and to the right of the hat, the line of demarcation between it and the limestone above being sharply defined; it is seen to thin out rapidly back from the quarry face.

At the base of the triangular opening, between the two beds of limestone that come in contact at that point, the Devonian material extends both to the right and to the left for several feet, forming a bed an inch or two in thickness between the two limestone beds. This bed has every appearance of having been deposited upon the lower limestone bed before the upper one was laid down, but in reality it was deposited at a much later date in a cavity which existed there near the close of Devonian time.

The sort of unconformity presented by this occurrence of Devonian sediments deeply buried in the Niagara limestone is peculiar. No description of any similar occurrence has been observed in the literature, and it may be designated by the name subterranean unconformity.

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DESCRIPTIONS OF NEW SPECIES OF DIPLODUS TEETH FROM THE DEVONIAN OF NORTHEASTERN ILLINOIS

ISOLATED tricuspid teeth with a minute median denticle, similar to those of the Carboniferous and Permian genus *Pleuracanthus*, are provisionally grouped under the name of *Diplodus*, and it has been customary to distinguish the so-called Diplodont and Cladodont types of Elasmobranch dentition according to the relative sizes of the median and lateral cusps. But since the discovery of *Chlamydoselache* in recent seas and the remarkable *Pleuropterygii* from the Cleveland Shale (Upper Devonian), it appears that the above types of dentition were common to several groups of primitive sharks, thus vitiating all generalizations based on the distribution of detached teeth. That species founded on such variable and fragmentary remains can have only a provisional value, pending the discovery of other parts of the skeleton, is further emphasized in the case of some Pleuracanth fishes, which have several forms of "Diplodus" teeth occurring in different parts of one and the same mouth.

As will be pointed out in the following, there are forms of *Phoebodus* teeth intermediate between *Diplodus* and *Cladodus*. This is interesting on account of the close parallelism displayed by teeth adapted for piercing among more or less widely separated groups, but as for throwing light on the interrelationships of these "genera" is wholly without significance. The earliest and most primitive forms of piercing teeth are typified by *Protodus* and *Doliodus* from the Lower Devonian of Campbellton, New Brunswick. *Cladodus* is first met with in the Corniferous limestone of Ohio, and the two new *Diplodus* species described below are the oldest known representatives of that genus. Mr. Stuart Weller, who discovered the material and kindly invited its description, regards the horizon as Uppermost Devonian. The locality is near Elmhurst, Illinois.

Diplodus priscus sp. nov. (Pl. VII, Figs. 1, 2)

Teeth minute; the two principal cusps of dental crown divergent and slightly inclined backward, robust, conical, round in section, without lateral carinae; coronal surface marked with relatively few, prominent, slightly curved striae extending from the base nearly to the extremities on the anterior face, but shorter and usually fainter on the posterior face. Median denticle slender, sometimes much reduced, or in one specimen apparently wanting altogether. Anterior border of root slightly produced downward; lower surface concave, elliptical in outline; posterior button present.

About a dozen examples (chiefly fragmentary) of this species were obtained by Mr. Weller, the largest of which has a total height of 8 mm. One fragment, consisting of the root only, has an elliptical, concave base, with axes measuring 5 mm and 7 mm; a similar but smaller root has axes of only 2 mm and 3 mm respectively. Each of the cones shown in Fig. 2 has eight vertical striae on the anterior face, but if any were present on the posterior face, they occurred higher up than on the part preserved. The length of the median denticle is conjectural, as the tip is missing from all specimens. The intermediate space is occupied by a groove in the tooth shown in Fig. 2, and to all appearances no denticle was present here. This, of course, must be looked upon as an exceptional variation.

Diplodus striatus sp. nov. (Pl. VII, Figs. 3, 4)

Of this species only a few fragments were obtained by Mr. Weller, the largest and most perfect being shown in the accompanying figures. It attains apparently about twice the size of the preceding form, and is readily distinguished by its finer striation, shallower root, and somewhat compressed section of its principal cones. The striae on the anterior face all curve uniformly in a spiral direction (Fig. 4, left-hand figure), but on the posterior face the tendency is to curve outward on either side of the median line to the lateral margin of the cones, where they terminate, exactly as in some species of *Cladodus* (*e. g.*, *C. striatatus* Ag.). This condition is partially indicated in the right-hand illustration of Fig. 4, but other specimens show it more distinctly. One or two fragmentary cones have the striae less

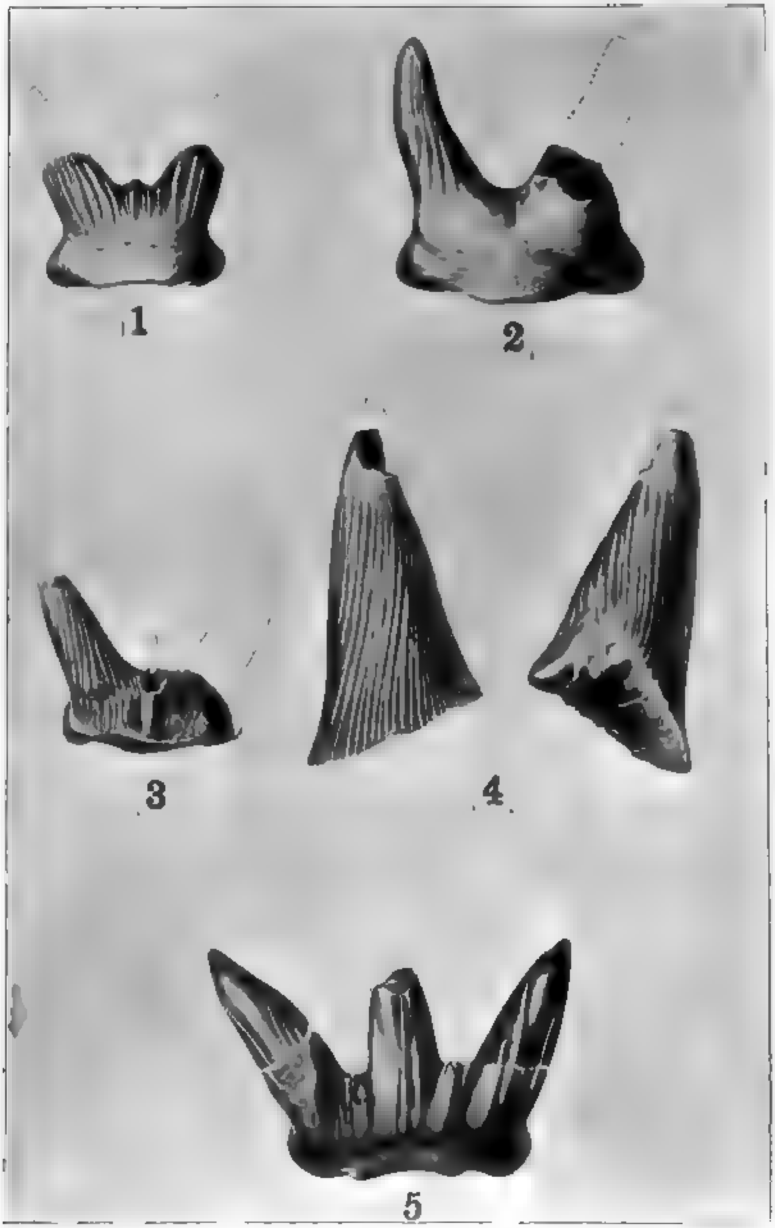
prominent and less numerous on the posterior face, and near the base they may become obsolete altogether. None of the specimens show the full length of the median denticle, but it was apparently long and slender. Further material will be required before the characters of this species can be adequately defined.

Phoebodus politus Newberry (Pl. VII, Fig. 5)

The two new species of *Diplodus* described above differ from most Pleuracanth teeth in an important character which they share in common with Cladodont dentition, and that is the striation of the coronal surface. The concave under surface of the root, peculiar projection of the front margin shown in Figs. 1, 2, and 5, together with the posterior "button," are features quite as characteristic of *Phoebodus* as of the two species of *Diplodus* just considered. As already stated, the form of teeth exhibited by *Phoebodus* is intermediate between *Cladodus* and *Diplodus*. Starting with the latter genus, the transition to *Phoebodus* is accomplished by imagining the median denticle to increase in size until it equals the lateral cones. Further increment in size of the median cone, or reduction of the lateral cusps, which amounts to the same thing, transforms the tooth into *Cladodus*. It is noteworthy that in *Cladodus*, when several lateral denticles are present, the outermost are almost invariably the strongest, and the smaller ones would thus correspond to the intermediate denticles of *Phoebodus*.

Phoebodus politus and other Devonian species have the intermediate denticles well developed, as shown in Fig. 5, but in an unpublished[1] species discovered by Professor W. C. Knight in the Permian of Nebraska, and also in the Triassic *P. brodiei*, only the three principal cones are present. While the coronal surface is striated in the earlier species of *Phoebodus*, it later becomes smooth, and the same observation holds true of *Diplodus*. All three genera under consideration appear to have had teeth

[1]The original specimen is listed as "*Diplodus* sp. nov." in Professor Knight's article on The Nebraska Permian in the last number of this JOURNAL (pp. 372–374).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omplicated in one way or another in the beginning, eventually ecoming more simplified. But, although mutual resemblances nd even intergradations exist, these all seem to be due to paral- elism of adaptive modifications.

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EXPLANATIONS OF FIGURES.

FIG. 1, 2. *Diplodus priscus* sp. nov. Anterior face.

FIG. 3. *Diplodus striatus* sp. nov. Anterior face.

FIG. 4. *Diplodus striatus* sp. nov. Anterior and posterior views of a large etached cone, apparently belonging to same species as Fig. 3. Originals of Figs. -4 from Upper Devonian, near Elmhurst, Ill.

FIG. 5. *Phoebodus politus* Newb. Anterior face. Cleveland Shale, Lorain ounty, Ohio. Original in Museum of Comparative Zoölogy, Cambridge, Mass.

All figures enlarged five times the natural size.

DIPTERUS IN THE AMERICAN MIDDLE DEVONIAN

LAST summer, while engaged in field work in Muscatine county, Iowa, the writer found a tooth of *Dipterus calvini* Eastman in the Cedar Valley limestone at Fairport, on the north bank of the Mississippi. It belonged to a horizon some eight or ten feet below the highest ledges of this limestone exposed

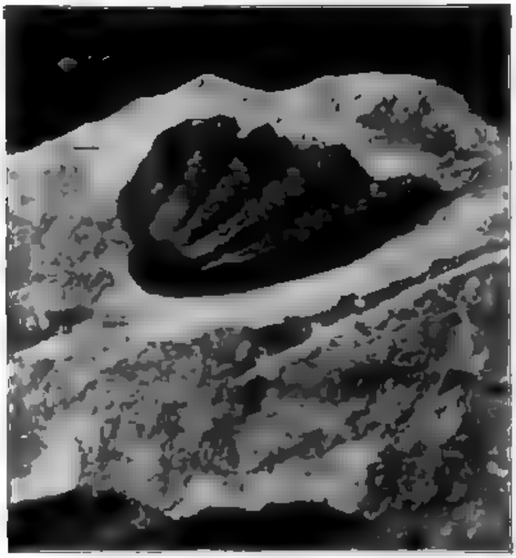

FIG. 1.—A tooth of *Dipterus*, sp., from the base of the Cedar Valley limestone, near Buffalo, Iowa, natural size.

in the county. A few feet below these ledges there are seen two black layers of porous bituminous rock.[1]

This horizon is characterized by a fauna more rich in lamellibranchs and gasteropods than that of the ledges below. There is also to be found one or two species of *Cranaena* and a form of *Strophaeodonta demissa* with coarser costae than usual. This

[1] These ledges have been called the Straparollus ledges. See Iowa Geol. Surv., Vol. IX, Pl. VI.

fauna comes in above the ledges from which Owen collected fossils that he referred to the Chemung ("*Spirifer euruteines*," etc.).

Lately I have found another somewhat more strongly tuberculated tooth of *Dipterus*, (see Fig. 1) near Buffalo, Iowa, at a level about 25 feet lower down in the same limestone. The ledge from which this tooth came, contains *Striatopora rugosa* and *Megistocrinus latus*. It is directly under the ledges in which Spirifer parryanus first appears. It has yielded teeth of *Ptychtodus* and fragments of *Dinichthys pustulosus*. Some coral-bearing ledges, full of fossils, lie four or five feet above it.[2] The ledge belongs to the Hamilton as described by Worthen in Rock Island county, Illinois, on the opposite side of the Mississippi, and comes in some fifteen or twenty feet above its base.

While this fish is reported from the Lower Devonian in Europe and Great Britain, it has not before this, I believe, been observed as low down as the Middle Devonian in America, to which age American geologists have referred the fauna of this limestone.

J. A. UDDEN.

[2] Megistocrinus bed. Iowa Geol. Surv., Vol. IX, Pl. VI.

STUDIES FOR STUDENTS

A CENTURY OF PROGRESS IN PALEONTOLOGY

THE presence of fossils in the rocks was observed by the ancient priests of Egypt, by the Brahmans of India, and by many other ancient peoples. In some cases the bones of gigantic mammals, such as the mammoth and mastodon, were observed, and, being considered as human bones, they gave origin to many of the beliefs in the existence of races of giants. The Greeks and Romans also observed fossil shells, bones, and plants, and some of their philosophers speculated as to their origin, although little or no progress was made in their study. Some of these men believed that the shells found preserved in strata far inland were really the shells of once living animals, while others, with Theophrastus, "supposed them to be produced by a certain plastic virtue latent in our earth."

It was not until the early part of the sixteenth century that geologic phenomena began to attract the attention of the Christian nations. At that period an animated controversy sprang up in Italy concerning the true nature and origin of marine shells and other fossils found abundantly in the strata of the peninsula. In the year 1517 extensive excavations were made in Verona, which brought to light a multitude of curious petrifactions, and furnished matter for speculation to different authors. Among these was Fracastoro, who declared "that fossil shells had all belonged to living animals, which had formerly lived and multiplied where their exuviæ are now found." He exposed the absurdity of having recourse to the plastic force of Theophrastus, which had power to fashion stones into organic forms, and also demonstrated the futility of attributing the situation of the shells in question to the Mosaic deluge, a theory that was obstinately defended by some. Fracastoro, however, had but few companions in his clear and philosophical views, and for nearly

three centuries two simple and preliminary questions were vigorously discussed — (1) whether fossil remains ever belonged to living creatures, and (2) whether, if this be admitted, all the phenomena could not be explained by the deluge of Noah.

Throughout all this long controversy regarding the nature and origin of fossils, little was done in the way of description of fossil forms; but with the reformation of the system of nomenclature by the introduction of the binomial system, instituted by Linnæus during the latter half of the eighteenth century, the way was opened for a more accurate description of fossils than had been practicable previously. Linnæus himself described and named some species of Silurian fossils from Sweden, among which may be mentioned the well known and widely distributed *Atrypa reticularis* and *Halysites catenulatus*, although the genera in which these species are now placed are of later date.

The real scientific study of fossils may be said to have begun with about the opening of the present century. William Smith (1790), in England, had recognized the value of the fossil contents of the rocks in tracing the strata over extended areas, but he did not devote his time to the description and naming of the fossils which he found. At about this same time rich stores of beautifully preserved fossils were discovered in the immediate neighborhood of Paris. The labors of Cuvier and Brougniart upon the vertebrates, and of Lamarck upon the fossil shells of this area, constitute some of the earliest really scientific investigations of fossil organisms. In fact, it may be said that Cuvier laid the foundation of the science of paleontology, when in 1797 he called attention to the fact that elephant bones discovered in the Paris basin were different from the bones of living species, and thus drew a distinction between living and extinct animals as implying present and past groups of living organisms.

Many of the works on paleontology published in the early part of the present century exhibited little or no attempt at classification of the materials described. The classic work of James Sowerby, entitled "Mineral Conchology," which was published in seven volumes, the first of which bears the date 1812

on the title-page, and the sixth 1829, a work in which very many of the species of British fossils were originally described, may be taken as a type of this group of works. In the arrangement of the matter included in these volumes no attempt is made at classification, either zoölogically or according to the geologic horizons in which the fossils were found. It is simply a paleontologic scrapbook, as it were, of descriptions and illustrations of fossil species. One plate, with its accompanying descriptions, may be devoted to Tertiary gastropods, the next to Paleozoic brachiopods, a third to Cretaceous ammonites, a fourth to Tertiary gastropods again, and so on, the total number of plates in the whole work being 648.

Following the early period in which there was to a great extent an absence of classification, the classification of fossils gradually developed along two distinct lines. On the one hand, with the increase of knowledge and with the progress in taxonomy of living organisms, the zoölogical classification of fossils made rapid strides, and many orders, families and genera founded wholly upon fossil forms were established, and were fitted into the scheme of classification of all organisms, making it far more complete than it could ever have been made from the study of living organisms alone. On the other hand, there grew up a classification of fossils into faunas, so that a whole series of extinct faunas, from the earliest Paleozoic time to the recent, were recognized. It also gradually came to be established that the sequence in time of extinct faunas, in their larger characteristics, was the same for all parts of the world where fossils were found.

For many years these two systems of classification of fossils went forward hand in hand, but with the development of the science the two paths along which progress was being made became more and more divergent, until at the present time the two divisions of the subject have become fully differentiated.

It is of interest to trace the differentiation of these two lines of progress in the life work of such a paleontologist as the late James Hall, whose career extended over more than half a century.

In the earlier volumes of the paleontology of New York, the faunal classification of fossils is predominant. Many new species and genera are described as members of the faunas under discussion, there being no elaborate investigations into the natural taxonomic grouping of organisms. In volume four of the work we begin to see the deviation of the line of investigation toward the biologic side, the faunal grouping being made subordinate to the taxonomic. This same subordination is seen in volumes five, six, and seven, while in volume eight we find the faunal classification entirely displaced, and the whole volume devoted to the treatment of the genera of Paleozoic brachiopods. We have, therefore, in this series of volumes an exhibition of the development of the science as illustrated by the life work of one man, from the faunal classification in 1847, through the mixed faunal and biologic, to the purely biologic classification in 1894.

This differentiation of the science, which has become nearly accomplished at the present time, is well exhibited in the character of the paleontologic monographs which have been published during the past decade or less. On the one hand such works as Wachsmuth and Springer's monograph of the "Crinoidea Camerata," a work which is strictly biologic in its treatment of this extinct order, is an illustration of one division of the subject, and on the other hand may be mentioned Walcott's "Fauna of the Olenellus Zone," where the biologic treatment of the fossils is made entirely subordinate to their faunal associations.

While these two branches of paleontologic science have been differentiating, the older method of investigation has by no means disappeared, and during this whole century of progress there have been appearing constantly contributions to paleontology of the "scrapbook" order. Among the more recent of these made upon a large scale may be mentioned the series of bulletins which have been issued from the Illinois State Museum of Natural History during the past decade. In these contributions some hundreds of species have been described, belonging to various classes and orders of organisms and from various geologic horizons, but they have contributed little or nothing either to the

taxonomy of the subject or to the faunal relationships of the fossils described. Such work, however, is valuable even today in so far as it is accurately done, because it relieves the investigator in the more special lines of research from a vast amount of labor. Every species of fossil must have a name as a sort of handle by which it may be manipulated, but with the more special workers in the subject, the description of species and the giving of names is but a means to an end, the discovery of new species not being the ultimate result sought after.

The biologic division of paleontology consists of the study of the structure and organization of individuals, of their ontogenetic development, of the relationship of species to species and of genera to genera, and of their phylogeny, all with the ultimate end of establishing as nearly as possible a natural classification of all organisms. A large proportion of all the work being done today among fossil vertebrates comes into this category. Among the invertebrates much work of a high order is also being accomplished. The recent contributions by Beecher upon the structure, ontogeny, and classification of trilobites and of brachiopods may be mentioned, also the contributions by Hyatt and others upon the cephalopods.

The faunal study of fossils is intimately connected with geology, in fact no history of the earth, from the period beginning with Cambrian time, can be made complete when the life history is excluded, and for this reason this faunal study of fossils is coming to be called paleontologic geology. Instead of taking a single species or any taxonomic group as the unit of study, as is done by the biologist, organic societies, those organisms which lived in a single locality under similar environment during a limited period of time, are the subjects of investigation. The fossil societies or faunas are dissected into their various elements, their relation to the environment in which they existed are studied, their relations to neighboring societies or faunas, both in time and space, and their migrations are the subjects of investigation. The study is a history of organisms in its broadest sense, and it is just as truly an historical study as is the study of human his-

tory. In fact many parallels may be drawn between this history of faunas and the history of the races of men.

Those organisms which are preserved in the sedimentary rocks, and among which our historical investigations may be carried on, are to a large extent the marine organisms which inhabited the shallow seas which have existed in past time upon the continental platforms, both on the borders and in the interiors of the continents. The life of the dry land, that of the fresh waters, and the aërial life, cannot have been preserved except under exceptional conditions. The ancient life of the abysmal depths of the oceans is unknown to us because of the entire, or at least approximate, absence of abysmal sedimentary deposits upon the continents.

Among the earlier geologists of the century, whose individual observations were limited to comparatively small geographic areas, at a time when the literature of geology and paleontology was but limited, the notion grew up that identity of fossil species and identity of age of the strata containing the fossils always went together. But gradually, with the increasing knowledge of living marine organisms, especially of their geographic distribution into more or less distinct provinces limited by physical conditions such as temperature, depth, ocean currents, purity of water, etc., and with the broadening knowledge of fossils themselves, when it came to be realized that the same organisms did not live everywhere at the same time in the past, but that, as now, there were also during all geologic time distinct zoölogic provinces inhabited by distinct faunas, and, furthermore, that these provinces were constantly changing their geographic boundaries, then the task of accurate or even approximate correlation of strata over any great distances from their fossil contents seemed to become almost hopeless. Indeed, so hopeless did the task seem to some that in 1862, in his presidential address before the Geological Society of London, Huxley[1] said: "For anything that geology or paleontology are able to show to the contrary, a Devonian fauna and flora in the British

[1] Q. J. G. S., Vol. XVIII, p. 46.

Islands may have been contemporaneous with Silurian life in North America and with a Carboniferous fauna and flora in Africa. Geographical provinces and zones may have been as distinctly marked in the Palæozoic epoch as at present, and those seemingly sudden appearances of new genera and species, which we ascribe to new creation, may be simply results of migration."

It was doubtless due to this seemingly more or less chaotic condition of the geographic distribution and the geologic range of fossils, that the majority of the students of extinct life during the latter part of the century have turned their attention to the biologic rather than to the geologic problems involved; but these very investigations which the biologists have made have materially assisted the paleontologic geologist in his researches. The biologic paleontologist may, and often does, carry on his investigations and make valuable contributions with little or no knowledge of the geologic phases of the science save the more or less dogmatic assertions of text-books. But the paleontologic geologist must of necessity follow closely the results of his biologic brother, though his own investigations may be something entirely different. In fact, the perfection of the taxonomy of fossils is to the paleontologic geologist but one of the means to an end, and not the ultimate end sought. The two divisions of the science may be compared with the ancient and the modern methods in the study of human history. The biologic division may be compared with the older method of historical study, in which the lives of a few conspicuous characters monopolized the whole study. On the other hand, the investigations in paleontologic geology may be compared with the modern scientific study of history, in which the evolution of society is made most prominent, the conspicuous characters being considered as the results of social conditions rather than as their causes.

At the present time it is believed by most, if not all, geologists and paleontologists that the great geologic systems represent practically the same time-periods throughout the world. It is also believed by many that the limits of the recognized

geologic periods, in so far as they are really natural divisions of geologic time,[1] are practically contemporaneous. It is also believed that about three divisions in each period may be usually detected with much certainty throughout the world, although the constitution of the faunas may vary to a considerable degree.

It becomes the task of the paleontologic geologist to investigate the fossil faunas, the organic societies of past time. Through a study of the geographic distribution of species and genera and their relationships to preceding and succeeding forms, the approximate limit of the zoölogic provinces of past time are determined, and from these data approximate restorations of the ancient geography are made. From a study of the changing physical conditions and the changing faunas are determined the migrations which we now know to have taken place and which Huxley suggested as a cause of sudden changes of fossil faunas.

Among fossil faunas as a whole there are two conspicuous types, (1) the cosmopolitan faunas and (2) the provincial faunas. At different periods of the earth's history these two types of faunas have been dominant. During Silurian time, for instance, there seems to have been in existence a great cosmopolitan, shallow-water, marine fauna, which is represented in America, in Europe, in Australia, and New Zealand, and probably will be discovered also in the other continents. The conditions for the development of such a fauna seem to have been the presence of widespread, shallow seas upon the continental platforms, epi-continental seas, as they have recently been called.[2] With broad seas of this sort around the borders of the continents, and extending into the interior by means of great tongues or lobes, and with conditions approximating base-levels upon the land, there would be a great limestone forming epoch, and with the probable atmospheric conditions of such an epoch[3] the tempera-

[1] See "The Ulterior Basis of Time Divisions and the Classification of Geological History," by T. C. CHAMBERLIN, JOUR. GEOL., Vol. VI, p. 449.

[2] JOUR. GEOL., Vol. VI, p. 602.

[3] JOUR. GEOL., Vol. VI, p. 609.

ture conditions upon the earth would be far more nearly equable than they are today, so that the same species could live both in the tropics and in the polar regions, as the distribution of the fossils indicates to have been the case. Under such conditions the shallow-water marine organisms would have the most favorable opportunity for intercommunication with all parts of the world, and there would be developed just such a cosmopolitan fauna as we know existed in Silurian time.

The Devonian period gives us a good illustration of the provincial type of faunas. During this period the shallow-water marine faunas exhibit a great diversity in various parts of the world. The Devonian faunas in New York, or even in southern Illinois, have less in common with those of Iowa, than have the Silurian faunas of the interior of North America with those of Europe or even with those of Australia. The Devonian faunas of Europe are also different from the American, and, furthermore, they differ among themselves. In South America and other parts of the earth there are still other types of Devonian life. The evidence afforded by the distribution of species and genera indicates without a doubt that the provincial development of faunas was one of the most conspicuous characteristics of the period. This type of development was, of course, brought about by the greater or less isolation of great shallow-water tracts in different parts of the world, in each of which the evolution of the life progressed along its own peculiar lines, molded by the particular environmental conditions which obtained in each tract or province.[1] Because of the more or less complete isolation of these various provinces, and the absence of shallow-water paths along which intercommunication between distant parts of the earth was possible, the development of a cosmopolitan fauna such as existed in Silurian time was out of the question.

In addition to the provincial development of the Devonian faunas, the life history of the period is complicated in a still further degree by reason of the continuous changes in the

[1] See "A Systematic Source of Evolution of Provincial Faunas," by T. C. Chamberlin, JOUR. GEOL., Vol. VII, p. 597.

geographic limits of the provinces themselves. The major development of the several great Devonian provinces was, in all probability, in shallow seas upon the borders of the continents, and the more important changes in their areal distribution was probably due to the cutting away of barriers formed by the more or less elevated rim of the continents, and the extension of lobes of the sea into the interior, so forming interior epicontinental seas. It is in the sediments of these interior epicontinental seas that the greater portion of all our Paleozoic life records are preserved. The borders of the continents are the chief regions of disturbance during periods of dynamic activity, so that the records of the life in the normal border provinces of such a period as the Devonian are to a great extent destroyed.

If we were able to possess ourselves of sufficient data in regard to the border provinces, it is probable that no sharp life breaks would be found, but in the interior epicontinental seas, the case is very different. By the slow cutting away by erosion of the barrier rim, or by the local sinking of the land, communication is established successively between the interior seas, and first one and then another of the great border provinces, and there are successive incursions of very different faunas, which make their appearance in the interior very suddenly, although their evolution has been in progress in some border province during a long lapse of time. As an illustration of such a sudden appearance of a fauna into an interior epicontinental sea, the fauna of the Corniferous in eastern North America may be mentioned. This fauna with its large number and variety of corals, its great number of cephalopods including the first goniatite, and, most of all, the host of armored fishes, appears with comparative suddenness, probably from the north through Hudson Bay, and includes many organisms which could not possibly have been derived from the preceding Devonian faunas, the Oriskany and Helderberg. The evolution of this fauna had probably been in progress during all the preceeding time since the Silurian in its more or less isolated province, but its appearance in the

interior epicontinental sea of Devonian time in eastern North America was relatively sudden.

Such a sudden appearance, in a series of sedimentary rocks, of a new fossil fauna, with apparently no genetic predecessors in the immediate region, may be compared with the sudden appearance in North America during the sixteenth century of the advanced culture and civilization of Europe among the savage tribes which had occupied the continent previous to that time. Although the appearance in America of the white man with his advanced culture was sudden, and his influence spread so rapidly that it soon drove into practical extinction the preëxisting and less advanced culture of the Indian, it was really the culmination of a long and gradual development, in Europe, of the art of building and sailing ships. In a similar way the sudden appearance of a new fossil fauna in a series of sedimentary rocks may be but the culmination of some physical change which has been in progress during an extended period of time. The submergance or the erosion of a land mass may be slow, and may continue through a long lapse of time, but the culmination of the phenomenon will be when the land passes below sea level, thus removing a barrier and allowing the immigration of a marine fauna into a region previously occupied by a very different assemblage of organisms. The conflict following such an immigration may be compared with the conflict between the Indian and the European cultures in America.

The resulting fauna from any such incursion and mingling within an interior sea, as has been described above, will of course be different from either of the original faunas. The Corniferous fauna in eastern North America, in addition to that element which came in from the outside, contains also an element which may be traced directly back to the preceding Oriskany or Helderberg faunas which had inhabited the same region. When the German tribes made their incursions into the Roman Empire, bringing in a new culture, the old Roman civilization and culture was not entirely destroyed, but there was built up a new civilization and a new culture, differing from either the Roman or the

German, which included elements from each. In the same way a resultant fauna, formed by the mingling of two or more faunas, will contain elements from each which can be detected by a careful study and dissection of the entire assemblage of organisms.

In general, the species in any fossil fauna fall into one of two categories: (1) indigenous evolution species, or those whose ancestors have lived in the same region and whose evolution has there taken place, and (2) immigration species whose ancestors have lived in some other geologic province and whose sudden appearance in the fauna under consideration is due to an immigration from the outside. It is the work of the paleontologic geologist to investigate each species of the fauna he may be studying, to determine in which category each belongs, and in the case of the immigration species to determine in what part of the world or in what geologic province its previous evolution has taken place, and what are the probable paths of migration.

In the historical study of fossil faunas it is interesting and suggestive to draw parallels with the history of human races. Until comparatively recent times there has been a remarkable provincial development of the races of men. Among the more primitive peoples a range of mountains or a great river was a sufficient barrier to prevent migration, because, as in the case of the provincial faunas, they had not means at hand for intercommunication between the separated provinces. But there has been a gradual development among the human races, of means of communication, first by beasts of burden and later by mechanical devices, until today, through the agency of the great ocean steamers, the transcontinental railways, and the telegraph, no corner of the inhabitable earth can be said to be isolated. With the increased facilities for intercommunication, there is being developed a great cosmopolitan human race, which will in time inhabit the whole earth, just as in far-away Silurian time there was developed, by reason of the widespread shallow waters upon the continents, a cosmopolitan fauna which reached from North America to Australia.

The questions involved in this faunal history of the earth are

complicated, but the fossils imbedded in the rocks are the data, and these are far more indisputable than are the data upon which ancient human history is being built. A recent writer gives the following definition of ancient history:[1] "A confused jumble of traditions, distorted to suit special pleaders; then rejumbled, and mixed, and confused, and redistorted according to the design of each new writer—the story of noble actions of big-minded men recast in the crucible of petty intellects, untrained in public life and unfit to grasp even the commonplace—the story of petty actions seized upon by enthusiasts and exalted into a nobility which would have been beyond the recognition of the original actors—all sorts of stories attempted to be told by weak, incapable men without purpose, or by unconscientious men or wilful liars with a purpose—obscure acts twisted into curious shapes in the brains of industrious writers—truth taken by well-meaning men and so changed by ignorance and lack of comprehension and unfitness to judge that it loses all semblance of its original self and becomes a misshapen, irrecognizable, utterly twisted and contorted thing, without much more than a vestige of fact upon which it is supposed to be based. This is ancient history." If the human historian is able to build up a story of the human race from such data, how much more certainly will the paleontologic geologist, by diligent study and investigation of his absolutely indisputable data, be able to build up a creditable history of the life of the earth since Cambrian time.

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[1] JOHN BRISBEN WALKER, in The Cosmopolitan, March 1899, p. 476.

EDITORIAL

"ABOUT a Reform in Nomenclature" is the title of a communication in the issue of *Science* for July 28, by A. L. Herrera, of the National Museum of Mexico. Preliminary to a specific suggestion, attention is called to the almost insupportable burden into which the nomenclature of the natural sciences has grown and to the imminent need of reform. The meaninglessness of many current names is a serious hindrance to the dissemination of science. "The language of science is more difficult than science itself."

The need of reform can scarcely be urged too strenuously, and every voice raised in its interest is welcome. There is, nevertheless, occasion for great circumspection in the adoption of substitutes for the present names. It is possible, perhaps, to make matters even worse than they now are. There is some ground for the suspicion that this might be true of the proposed reform, the chief features of which are as follows:

The generic names of animals to end in *us*, those of plants in *a*, and those of minerals in *i;* minerals, to have generic names formed from abbreviations of the names of their chemical constituents, as *sulphurzinci*, *sphalerita;* the generic names of plants to be preceded by abbreviations of the family names, as *Rosaspiræa limbata;* with a similar device for the names of animals.

One of the most serious faults of the present binomial system is its instability, due to changes of reference of species to genera. This is especially true in paleontology where the original data were imperfect and new discoveries are being constantly made, and are sure to continue to be made for a long time to come. Now, to add the name of the family in the form of an abbreviation-prefix would introduce another variable factor, one, perhaps, even more subject to change than the generic

reference. Furthermore, the addition of the prefix would make the already cumbrous nomenclature still more ungainly. Reform should move in the direction of simplicity and fixity as well as significance.

In naming minerals there is no occasion for the introduction of the bungling binomial system. There would be an obvious advantage in deriving the names of minerals from those of their chemical constituents, as suggested, but if this is done a uniform terminal syllable is a pedantic superfluity. *Sulfozinc* would sufficiently show that the subject was not a plant or an animal, without the terminal *i*. So also the *sphalerita* becomes nearly needless and quite incongruous, as it belongs to the meaningless system which it is proposed to eliminate. In place of it a syllable to express the form of crystallization would carry out the fundamental idea.

The most hopeful suggestion yet made for mineralogical nomenclature proposes that the names shall consist simply of a combination of syllables which shall indicate the crystalline form and the essential chemical constituents, since these are the characterizing elements. The main difficulty of such a system lies in securing brevity and euphony. It would be easy enough to improve upon the present uncouthness in the main, but not to reach good phonic combinations in all cases. Much could be done, however, by leaving out all useless lumber and all superfluous tailpieces, by reducing the abbreviations to their lowest terms, and by giving them the best possible combining forms. If this required that some liberties be taken in forming the abbreviations it would be merely introducing into language that regard for economy and utility which characterizes progress in all the live arts. T. C. C.

REVIEWS

RECENT BOOKS ON PHYSIOGRAPHY

Rivers of North America. A Reading Lesson for Students of Geography and Geology. By ISRAEL C. RUSSELL. Pp. 326. G. P. Putnam's Sons, 1898.

Earth Sculpture, or the Origin of Land-Forms. By JAMES GEIKIE. Pp. 397. G. P. Putnam's Sons, 1898.

Physical Geography. By WILLIAM MORRIS DAVIS, assisted by WILLIAM HENRY SNYDER. Pp. 428. Ginn & Company, 1899

These three volumes deserve the careful attention of teachers and students of physical geography and geology, not only in secondary schools, but in colleges as well. Some of them should also appeal to a large class of readers who are lovers of nature, though their work is not in educational lines.

Professor Russell's book is well described by its explanatory title, "A Reading Lesson for Students in Geography and Geology." In this volume the author has presented in readable form the leading processes and principles involved in the history of rivers. In addition, he has introduced, as the title suggests, much descriptive matter concerning the rivers of our own continent. The matter is not too technical for the high school student who is serious in his work, and will be read with profit by college students who have rarely had a physiographic topic so well presented on the printed page.

The scope of the book is in a measure indicated by the headings of the various chapters: The Disintegration and Decay of Rocks; Laws Governing Streams; Influence of Inequalities in the Hardness of Rocks on Riverside Scenery; Material carried in Suspension and in Solution; Stream Deposits; Stream Terraces; Stream Development; Some of the Characteristics of American Rivers; The Life History of a River.

In treating of these various topics the author has made no attempt to be exhaustive, for the book has been prepared, not for the professional geographer, but for the general student who has had too little

readable matter at his command. The advanced student may wish that the book were fuller and more explicit at some points, while others into whose hands it will fall, will wish it more elementary. Such infelicities are not to be avoided, and it would have been difficult, on the whole, to have made a better selection of material. Important topics have not been omitted, and unimportant and irrelevant ones have not been introduced. Throughout the book the modern nomenclature of rivers has been used, and on this account those who have not followed the progress of geographic science during the last ten years will find it to their advantage to read the book in course, rather than otherwise.

The volume has some effective illustrations, though their number is too small (17 plates and 23 figures in text), which add to its otherwise attractive appearance.

Professor Geikie's volume deals with the processes involved in the development of topography, and with the results which these processes have effected. The first chapter is devoted to a general discussion of the agents of denudation. The principles and processes of denudation are then studied with immediate reference to land masses affected by various types of structure. The topographic forms developed in regions of horizontal strata at various stages in the progress of denudation and under various conditions are first considered. The same principles and processes are then applied to regions where the strata are inclined, and the topographic results under these conditions are described and illustrated, as in the preceding case. Passing from the more simple to the more complex, the effects of denudation in regions of folded and highly disturbed strata are next set forth, and numerous cuts are introduced illustrative of the more complex topographic forms which result from denudation where the stratigraphy is complicated.

The consideration of the topographic forms developed by denudation in regions possessed of various types of stratigraphy is followed by a consideration of the topographic effects of faults, and of volcanic and other types of igneous action. Unfortunately the last of these topics is less adequately illustrated than most of the preceding. The lack of illustrations here may be less serious than it would have been elsewhere, since illustrations of the topographic effects of volcanic action are among the most common in our geographies. Nevertheless, the absence of abundant illustrations seems to us a defect.

Following the discussion of these topics, a chapter is devoted to the topographic features which depend for their existence upon the character of the rock rather than upon the position of its beds. The topographic effects of structure other than stratification and the results of the varying composition of rock are considered.

To the topographic effects of glaciation two chapters are given, and while the text is clear, no virtue which it possesses can compensate for the entire absence of cuts illustrative of the points described. Nowhere are illustrations more needed, and in no field are they more easily obtained. The topographic effects of eolian action, involving a brief consideration of dunes and of rock sculpture effected by the wind, and of the surface effects of underground water, are next considered. In the case of the last topic, illustrations are again altogether wanting.

A chapter is given to the discussion of basins (depressions without outlets), and illustrations showing the real nature of basins are introduced which will tend to correct the prevalent erroneous notions concerning the shape of these topographic features. The topography of coast lines is briefly discussed, and too meagerly illustrated. It is with regret that the lack of illustrations is repeatedly referred to, but in a book of this sort, which deals almost exclusively with the forms of the surface, the lack of illustrations is especially serious.

The volume closes with a classification of land forms. It is to be especially noted that the classification comes in the right place, after (and not before) a consideration of the processes of earth sculpture and their results, and therefore when the reader is for the first time in a position to appreciate the force and the meaning of the classification. This is a point which the writers of books intended to be educational would do well to note. Many of our text-books are lumbered with elaborate synoptical classifications preceding the discussion of the things which are classified. When the classification in such positions is reached by the student he has no comprehension of its meaning, and too often does not refer to it after the chapter is read.

In spite of the one notable defect which has been referred to, Professor Geikie's book is to be heartily commended to students and teachers of geography.

Professor Davis's book differs from the others in being a text-book. The author has followed traditional lines to the extent of including in the volume a consideration of the atmosphere and the ocean as well

as the land; but he has departed from traditional lines in according to the former topics but brief treatment, while the larger part of the book is devoted to the geography of the land. The author is understood to believe that the subject of meteorology should be separated from that of physical geography (of the land) and pursued as a distinct subject in the secondary schools. Whatever may be said of the desirability of this change, it is not likely to come about at present, and for a good while to come such attention as is given to meteorology in the secondary schools is likely to be in connection with physical geography. If this be true, the consideration of the atmosphere in this volume seems to us too brief; on the other hand, the selection of material is excellent, and in so brief a space it would have been difficult to present a more satisfactory outline of the subject. The inadequacy of the treatment, however, appears to be recognized by the author himself, who indicates that it should be supplemented by "local observations and by the construction and study of weather maps." Brief appendices give some suggestions for this observational and constructional work, but the average teacher in the secondary school will find these suggestions still more inadequate than the text they supplement. Much fuller directions will need to be given to teachers in the secondary schools before the majority of them can direct the sort of work which Professor Davis rightly advises.

The consideration of the ocean is likewise exceedingly brief (34 pages). Both the selection of material and its presentation are excellent, but the small amount of space devoted to the subject is insufficient to give even all the important points with which the student of the subject, even in an elementary way, should be acquainted.

As already noted, the larger part of the book is devoted to the consideration of the land surfaces, and it is not too much to say that the geography of the land is presented in an essentially new light. Here traditional lines are not at all followed, and no one whose knowledge of the subject has been derived from other text-books can read this without learning much concerning the subject and concerning the methods of presenting it. The descriptive element enters more largely into this volume than into most recent books on physical geography. Topographic types are illustrated by descriptive references to specific areas, many of which have not been well known to professional geographers. In other words, concrete illustrations of general types abound, and they are drawn from wide sources and are definitely pictured.

'lains, plateaus, and mountains as topographic types are considered in rder, and many illustrations of the various phases of these general ypes, drawn from all parts of the world, are introduced. The treat-ient of coastal plains is especially happy. The question might be aised whether the idea of the coastal plain is not carried rather far rhen, under the heading of "Ancient Coastal Plains," areas very dis-ant from the sea, and which now have nothing to suggest their 'coastal" relations, are discussed. Thus "the ancient coastal plains" of Wisconsin seem to us a little remote for consideration in an ele-nentary physical geography. The teacher who is a geologist as well as ι geographer will know how to treat this subject; but it seems to us ikely that the text will fail to convey the right notion of these "ancient :oastal plains," which are no longer coastal plains, to many pupils if ιot to many teachers.

The important chapters on Rivers and Valleys is excellent, and hould prove effective with classes if they have the guidance of skillful eachers.

A significant chapter of the volume is entitled Climatic Control of ˽and Forms. Here are considered such topics as the effect of climate on streams and their work; salt lakes; the life of arid regions; glaciers ιnd ice-sheets and their work. It must be confessed that the fashion-ng of the land surface by the continental ice-sheet of North America eems doubtfully placed in a chapter with the above title, for while glaciation was of course a result of the climate of the time, the topog-aphy which the ice fashioned is as really the work of the ice as the opography developed by rivers is their work; and it can hardly be said hat glaciers and ice-sheets are more directly controlled by climate han rivers are. The discussion of glacial topography under the cap-ion of Climatic Control of Land Forms, therefore, seems to us not he happiest possible arrangement. The volume closes with an excel-ent chapter on Shore Lines. Numerous brief appendices are added which will be helpful to the teacher of the subject.

Throughout the volume emphasis is laid on the effects of geogra-phy on human development, and references to historical incidents, as nfluenced by topography, are frequent. This is a phase of the subject which is most welcome.

In a book which is so thoroughly good it may seem gratuitous to mention defects, but there is one which seems to us somewhat serious. There is an occasional lapse into an obscure style, resulting from the

introduction of ideas for which adquate preparation has not been made, or from the two brief exposition of complex phenomena. The result is that the pupil, if not his teacher, will sometimes be staggered. From actual experience with a group of teachers, it has been found that a large proportion of them do not catch the idea of a *cuesta* (p. 133), and it is not easy to see what good purpose the introduction of the term serves, *for the pupils who will use this volume.* The defect referred to above will, it is to be feared, interfere with the usefulness of this very excellent book.

The volume is abundantly illustrated (261 figures and 10 plates) and every illustration is to the point. Half-tones have been excluded, and engravings put in their place. There can be no question but that in most cases the engravings are much more effective than reproductions directly from photographs, for the non-essential features are omitted, and the essential features brought into prominence. We have seen no text-book on this subject in which the illustrations so uniformly illustrate the exact points which they were meant to illustrate, and in such a way that their meaning cannot be mistaken.

The three volumes mentioned above put new and rich resources into the hands of teachers and students of physiography, and should result in great improvement in the teaching of the subject.

R. D. S.

Transactions of the Kansas Academy of Sciences, 1897–8. Vol. XVI.

This volume of 320 pages indicates a laudable degree of activity in various scientific lines. The presidental address by Dr. S. W. Williston on "Science in Education" is an admirable exposition of the existing status and current tendencies of education in liberal and professional lines and contains excellent suggestions relative to desirable changes in which science shall be a larger factor. The papers in geology and paleontology are six in number as follows: Physiography of Southeastern Kansas, by George I. Adams; *Fusulina cylindrica* Shell Structure, by Alva J. Smith; New Developments in the Mentor Beds, by A. W. Jones; Fossil Turtle Cast from the Dakota Epoch, by C. S. Parmenter: Deep Well at Madison, Kan., by F. W. Bushong; Correlation of the Coal Measures of Kansas and Nebraska, by J. W. Beede.

T. C. C.

Iowa Geological Survey, Annual Report, 1898, Vol. IX. By SAMUEL CALVIN, State Geologist; H. F. BAIN, Assistant State Geologist.

Statistics of Mineral Production. By S. W. BEYER; *Geology oj Carroll County,* H. F. BAIN; *Geology of Humboldt County,* T H. MCBRIDE; *Geology of Story County,* S. W. BEYER; *Geology of Muscatine County,* J. A. UDDEN; *Geology of Scott County,* W. H. NORTON; *Artesian Wells of the Belle Plaine Area,* H. R. MOSNAT. Thirteen plates, 56 figures, 14 maps.

This volume of the reports of the Iowa State Geological Survey serves to corroborate the high opinion already established among the geologists of the United States of the work of this organization. The record of the Iowa survey has been one of uninterrupted excellence in both the theoretical and the economic phases of its work. The list of the corps engaged in the work of 1898 is of itself sufficient to invite inspection of the report.

Each of the county reports gives a systematic exposition of the physiographic and economic features of the geologic field under consideration, each being emphasized as the peculiar characteristics of the district demand. To many of the reports is appended a discussion of the forestry of the areas studied.

In the geology of Carroll county the physiography is of exceptional interest, since the tract is bisected diagonally by the edge of the Wisconsin drift sheet. Consequently the northeastern and southwestern parts of the county display topographic features in admirable contrast as the result of these relations. The Middle Coon River follows this drift margin in a general way, receiving numerous tributaries with secondary and tertiary branches from the area of Kansan drift westward, while from the Wisconsin drift there is only one important tributary and that without branches. The erasure of post-Kansan drainage by the Wisconsin invasion is illustrated by a number of examples. The Coon River, flowing across the northeast part of the county has constructed a makeshift course from "bits of old captured valleys, and new trenches which it has cut for itself."

The stratigraphy of Carroll county includes an exposure of a Carboniferous limestone, probably of the Des Moines series. The Cretaceous is represented by several exposures of the Dakota sandstones and

conglomerates. Some of these conglomerates include silicified Niagara and Devonian fossils as part of the clastic materials. A few Cretaceous fossils have been identified. Undoubted chalk rock of the Niobrara, containing abundant *Inoceramus labiatus*, is exposed in one locality in association with the Dakota sandstone.

The Pleistocene deposits are considered in detail. A new development from the field investigation is the demonstration that much of the extra-Wisconsin drift, hitherto provisionally correlated with the Iowan, belongs to an anomalous phase of the Kansan, which shows many peculiarities, near the border of the Wisconsin, due either to some protecting influence during the period of post-Kansan erosion, or to some subsequent modification referable to the presence of the loess and the proximity of the Wisconsin drift. The loess is called Iowan in age and lies beneath the Wisconsin, except at some places where a thin mantle of it covers the edge of the latter, evidently as a recent wind deposit. The loess of this region is not of sufficient depth to have developed its own peculiar type of topography.

The coal prospect for Carroll county is an exceedingly uncertain problem and, in Dr. Bain's opinion, is to be solved only by the drill, and that only at large expense, chiefly because of the great depth of the drift. Moreover, the great distance from the known outcrops of coal make it possible that the productive measures may have thinned out altogether in Carroll county. The other mineral resources of the county are inconsiderable. The water supply is entirely sufficient. The area includes several artesian wells.

The report for Carroll county is fairly representative of the method and character of the work done in the other counties and only special details of the other papers demand consideration. Mr. T. H. McBride, in the report upon Humboldt county, identifies the Kinderhook and Saint Louis of the Mississippian series and the Des Moines of the Coal Measures. The latter is covered by the glacial series, of which the pre-Kansan, Aftonian, Kansan, Buchanan and Wisconsin are recognized.

The Wisconsin sheet is merely a thin veneer, conforming to the previously established Kansan-Buchanan topography. This is worthy of note in the light of other observations on the relations of recent drift sheets to underlying unindurated formations. The somewhat paradoxical inference is suggested that the ice sheet was normally less competent to disturb the surface of a deep formation of loose materials than the surface of an exposed indurated rock. A gravel formation,

as it was being overridden, became the basal part of the ice and exhausted to a degree its transporting capacity, forming the effective load of the natural stagnation zone at the base of the ice. Over a rock surface, on the other hand, the ice may have possessed its maximum of transporting and abrading power.

A unique detail in the drainage of Humboldt county is the practice, reported of draining kettle-hole lakes in certain districts by sinking wells through impervious layers to a porous stratum. The method appears to be effective and economical, though its sanitary bearing upon the drinking water of the region may be worthy of consideration.

A notable feature of Mr. Beyer's report on Story county, also of Professor Udden's on Muscatine county, is the determination of deformations. The gentle flexures, of which the Skunk River anticline is a type, are suggestive when considered with similar structures which have been reported at many points in the exposures of different formations across the upper Mississippi basin. The reiterated recognition of such structure suggests that the phenomena of crustal shortening have been restricted by no means to the mountain belts of the coastal regions but that these gentler flexures, affecting such immense areas, may have been, in the aggregate, an equally notable factor in the adjustment of the external masses of the earth to internal changes.

Mr. Beyer gives an excellent report on the stratigraphy, including many valuable well records. The discussion of the development of the Skunk River system is an instructive physiographic study. The course of the pre-Wisconsin channel, the transference of much of the Skunk River drainage area to the Des Moines system by the Wisconsin invasion, the post-glacial struggle of the stream toward readjustment, form the substance of a finely developed discussion. Remains of the Mammoth are reported by Mr. Beyer from an excavation four or five feet below the surface of the Wisconsin drift. Coal, clay and building stones are the economic products of Story county.

The report on Muscatine county by Professor Udden is characterized by carefully derived conclusions and is rendered thoroughly readable by the excellent style of presentation, and enjoyable by the variety of new and sharply observed phenomena. The stratigraphy of the county includes the Gower stage of the Niagara, Wapsipinicon and Cedar Valley stages of the Hamilton, Sweetland Creek beds of the Upper Devonian, Kinderhook group of the Mississippian and the Des Moines stage of the Coal Measures. This article contains an exhaustive discussion

of the drift with many close, but distinctly drawn, discriminations. The following Pleistocene formations are recognized: anteglacial silts, pre-Kansan, Aftonian, Kansan and Illinoian. The anteglacial silt is a new division. It is explained as having been formed by water and wind ahead of the invading pre-Kansan ice-sheet. If that be its origin, it might properly belong with the pre-Kansan drift and the division would appear unnecessary. If every aqueous deposit of the drift should receive a special name, the clarifying effects of analysis would soon be lost in confusion. The economic products of Muscatine county include coal, though in unprofitable amount, small quantities of gas, building stones and clay.

The geology of Scott county, by Professor W. H. Norton, contains much fresh information. The passages in the paper dealing with the history of the drainage and with the stratigraphy are of special value. Touching the former, this region is particularly interesting because of its location at the southern limits of the driftless area and the consequent complexity of the drift phenomena arising from the mutual interference of the ice lobes at this place.

The report on the artesian wells of the Belle Plaine area by H. R. Mosnat gives a thorough exposition of the geology of the water-bearing formation, the amount of the flow and the source of the water. The computations rising from the study of flow and supply develop many facts which simplify to a great degree the conception of the combination of conditions appropriate to the formation of artesian wells. A most significant passage is that discussing the rate of movement of the underground water through materials of different texture. It is estimated that nineteen years would be required for the water of the aquifer to move in a direct line from Vining to Ladora along the major axis of the artesian area. Hence, the writer concludes, the great exhaustion of the water body brought about at Vining by the remarkable flow of the great Jumbo well when it was opened, will not affect the flow at Ladora before the year 1905. He also shows the limited extent of surface actually necessary to supply the water for the aquifer and the adequacy of the rainfall to produce the supply without any recourse to the extravagant superstitions which have made this artesian area "the eighth wonder of the world" in the minds of the inhabitants of the region. The discussion is closed with a paragraph on the uses of the water, which largely relegates the wells to the category of interesting

geological phenomena whose practical and economic value is doubtful or, at any rate, decidedly limited.

This volume is carefully printed and amply illustrated by expressive and well selected photographs, sections and sketch maps.

J. W. FINCH.

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THE

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THE OZARKIAN AND ITS SIGNIFICANCE IN THEORETICAL GEOLOGY.

I. THE OZARKIAN.

IN 1886 I published a paper entitled "A Post-Tertiary Elevation of the Sierra Nevada, as shown by the River-beds."[1] Again in 1891 I published a paper on "The Mutual Relations of Land Elevation and Ice Accumulation during the Quaternary Period."[2] The following paper may be regarded as a continuation of the lines of thought suggested by the two preceding.

By continued reflection on the enormous changes that occurred in the western part of the continent at the end of the Tertiary, I have been led to recognize the existence of an epoch of long duration and of great importance immediately preceding the time of the invasion of the ice sheet. On account of its great importance this epoch certainly deserves a distinctive name. For want of a better, I adopt that of the "Ozarkian," given it by Hershey.

History of the name.—The epoch was first recognized by Hilgard and more distinctly by McGee, as the post-Lafayette uplift,

[1] Am. Jour. Sci., Vol. XXXII, p. 167, 1886.

[2] Bull. Geol. Soc. Am. Vol. II, p. 329.

shown by extensive erosion of the Lafayette gravels all over the southern states. But a distinctive name was first given it by Hershey,[1] who called it Ozarkian in commemoration of its work in the formation of the remarkable gorges of the region of the Ozark Mountains. He, however, fully recognized its importance as a time of general uplift and erosion, but regarded it as only an episode comparable with the Kansan or Iowan episodes of the Glacial epoch. The name was adopted, though somewhat reluctantly, by McGee (Sci. III, 796, 1896), and its importance more fully recognized,[2] but he regards it as belonging to the Pliocene and not the Quaternary. This point we shall discuss later. A little later (Am. Geol. XVII, 389, 1896) Upham also adopts the name, and, like Hershey, refers it to the early Quaternary, but advances it to a *primary* division of that period comparable with the Glacial. But even yet, it seems to me, its full importance is scarcely recognized unless it be by McGee, and its true significance entirely overlooked. Indeed both its importance and its significance are brought out in strong relief only by the study of its phenomena in the western part of the continent and especially in California.

If with Upham we divide the Quaternary period into three epochs, the Ozarkian, the Glacial, and the Champlain, then the Ozarkian was by far the longest, in fact, longer than both the others put together. Or again, if the Quaternary be divided into two epochs, the Ozarkian and the Glacial, the Champlain being merged into the Glacial, as is commonly done by European geologists, then of the two, the Ozarkian is by far — perhaps by many times — the longer. In many ways the Ozarkian is strongly contrasted with the other epochs of the Quaternary. If, for example, we adopt the division into three epochs, these are characterized each in its peculiar way; the first, by elevation; the second, by ice accumulation; the third, by depression; the first, by immense erosion; the second, by glaciation and drift deposit; the third, by stratified deposits in seas and lakes.

[1] Science III, 620, 1896.

[2] "The reference of the Ozarkian to the Pleistocene would multiply by many times the commonly recognized duration of that period." McGee, Sci. III, 796, 1896.

The Ozarkian has heretofore attracted little attention, because ıtil very recently geological history was supposed to be corded only in stratified rocks and their contained fossils; but ıis being a period of continental elevation and enlargement, it ıs left no strata exposed to view. Geological history was at ıat time recorded only by erosive work. So far as stratified ıcks and fossils are concerned, this is a period of lost record— is a *lost interval.*

I said that the real importance and significance of this epoch best seen on the western part of the continent. I must justify ıis assertion by a comparison of the phenomena in different ırts of the continent.

1. *The eastern part.*—In the eastern part of the continent, the ork of erosion of this time is seen in the so-called old river-ꞓds deeply underlying the present beds and extending beyond ıeir limits on each side, and especially continuing beyond the mits of the present continent, as submerged channels trenching ıe submerged continental shelf, notching deeply its margin and pening out into the abyssal waters of the true oceanic basin. : is shown also not only in the deep gorges of the Ozark region, ot only in the deep and widespread erosion of the Lafayette ravels in the south, but also in the highly emphasized topog-ıphy underlying the drift all over the glaciated region of the orth. By means of the submerged channels the amount of ver-cal elevation of the eastern portion of the continent has been stimated as certainly not less than 3000–5000 feet and may ave been much greater. Similar evidences of elevation are ound on the Pacific coast and also on the coasts of Europe and f Africa. We have every reason to believe that it was a time f almost universal continental elevation and enlargement.

Heretofore these old rivers of the east have been referred, ke those of the west, to the Tertiary times and called Tertiary ver-beds; although it is admitted that they were occupied and eepened by the ice of the Glacial times. The Tertiary erosion as supposed to have graded insensibly and continuously into ıat of the Glacial, but the greater part was attributed to the

Tertiary; and the post-Tertiary erosion was supposed to be wholly Glacial. According to my view, on the contrary, the post-Tertiary erosion was by far the greater and was pre-Glacial in time, *i. e.*, Ozarkian.

In the eastern portion of the continent, therefore, the Ozarkian grades into the Tertiary, but is well marked off from the present by the depression and sedimentation of the Champlain.

2. *The mid-continental or plateau region.*—In the plateau region, on the contrary, the Ozarkian work is sharply marked off from the Tertiary, but grades insensibly into that of the present.

It is well known that the plateau region has been rising ever since the end of the Cretaceous—that from being the lowest part of the interior continental basin, it has become the highest part of the continental arch. The amount of elevation during this time has been at least 20,000 feet, about 12,000 of which has been carried away by erosion, leaving still 8000 feet of general elevation. Of this enormous general erosion, the largest part—shown by the receded and still receding cliffs—probably belongs to the Miocene. The canyon-cutting is certainly post-Miocene. The outer canyon (of the Grand Canyon) ten to fifteen miles wide and 3000 feet deep, belongs to the Pliocene; while the inner gorge, 3000 feet deep but very narrow, belongs to the post-Pliocene, *i. e.*, to the Ozarkian and the present.

I said the Tertiary work is sharply marked off from the Ozarkian but the Ozarkian grades insensibly into present. The evidence of this is given by Dutton, as follows:

Between the Pliocene work of the formation of the outer canyon, and the subsequent work—Ozarkian to present—the cutting of the inner gorge, there was an interval of rest marked by a wide shelf between the two. The rising and the down-cutting was continuous during the Pliocene until finally the river reached its base level of erosion and rested from further downward cutting and commenced to sweep from side to side widening its channel, until the canyon walls were nearly ten miles apart. Then began the Ozarkian rise and the beginning of the

cutting of the inner gorge, which has continued to the present time. The elevation during the Tertiary was regional, the elevation which commenced with the Ozarkian was continental or even more widespread. In the east there was a sharp demarcation of the Ozarkian from the present erosion by the Champlain depression and sedimentation ; which depression, as I suppose, was determined by the weight of the ice sheet. But in the plateau region there was no ice sheet — it did not extend so far — and therefore there was no depression and therefore no interruption of the erosion to the present time ; for the rising is still progressing. The whole series of phenomena in this region may be well explained by a local rise continuous from the end of the Cretaceous till now, except that it was interrupted at the end of the Pliocene by the Lafayette depression of McGee and afterwards greatly enhanced by the general continental elevation of the Ozarkian.

3. *Sierra region.* — But it is in the Sierra region alone that we find the Ozarkian erosion-work sharply marked off both from the Tertiary on the one hand and from the present on the other. It is here therefore that the distinctive Ozarkian work can be best studied.[1]

Brief history of the Sierra.—The Sierra Nevada, as is well known, was formed at the end of the Jurassic by lateral pressure and strata-folding in the usual way. What kind of a mountain it was at that time, how high, and what its configuration we know not ; for the continuous erosion of the Cretaceous and Tertiary times had nearly swept it clean away. The cycle of its mountain life had reached its last stages. By continuous erosion it had been reduced to a peneplain, with its wide-sweeping curves of broad shallow channels and low-rounded divides. The rivers had reached their base levels and rested. This was the work of the Cretaceous and Tertiary.

Then came the post-Tertiary rejuvenation of the mountain

[1] As the term *Ozarkian* had already been used by Broadhead for a Lower Silurian series in the Ozark region (Am. Geol., XI, p. 260, 1893) there may be an admissibility of its use in this connection. If so, I would propose the name *Sierran* as far more appropriate.

life,[1] by the formation of a fissure on the eastern slope, the heaving of the whole mountain block on its eastern side with a great eastern fault-scarp, ; the transference of the crest to the extreme margin with great increase of the western slope and consequent revival of the erosive energy of the rivers. Coincident with this in middle California there was a great outpouring of lava which ran in streams down the western slope, filling up the old river beds, and displacing the rivers. The displaced rivers, with recently and fiercely aroused energy, immediately commenced cutting new channels, which are now 3000 to 6000 feet deep, and far below the old; so that these latter are left with their lava-covered gravels high up on the present divides This was the work of the Ozarkian. This intensely interesting geological story has been so often told that we only recall here its outlines in order to apply them to the case in hand.

In southern California, beyond the limits of the lava flows this post-Tertiary elevation and revival of erosive energy was fully as great, or even greater than in middle California ; but the rivers were not displaced, and therefore they continued to cut in the same places, but to far deeper levels ; so that the margins of the wide old river beds with their gravels are left hung up high on the sides of the present canyons.[2] The distinction, however, between the wide shallow tertiary troughs and the deep narrow post-Tertiary canyons is equally sharp here.

We have spoken thus far only of the deep canyons which trench the western slope as being of post-Tertiary origin ; but the same is true also of the whole scenery of the high Sierra. It all belongs to the post-Tertiary, and its bold, rugged, savage grandeur is due to its extreme recency. The wildness of youth has not been yet tempered and mellowed by age.

It is evident then that the Ozarkian is here sharply marked off from the Tertiary. How is it in regard to its relation to the present ? In the lower parts of the canyons the Ozarkian grades insensibly into the present, for the rivers are still cutting. But

[1] Am. Jour. Sci., Vol. XXXII, 167, 1886.

[2] Am. Jour. Sci., Vol. XXXII, 174, 1886.

ι their upper parts the two are separated by the glacier erosion. he upper canyons were occupied by glaciers, and the compari›n of these upper with the lower canyons shows that while their ›rms were modified, and perhaps their depths somewhat ıcreased, they were not made by this agency. This was mainly ıe work of the post-Tertiary but pre-Glacial times, *i.e.*, of the 'zarkian. But the glaciation serves to show how much has een done by water since the Glacial, *i. e.*, during the present mes; and we find it very insignificant.

In conclusion, no one who sees and reflects upon the prodiious work done in the Sierra since Tertiary times can resist the onviction that even making all due allowance for exceptional ıergy and rapid work, determined by high slope and also for ther causes of rapid work explained in a previous paper,[1] the me necessary must have been enormous—many times as great s any reasonable estimate of the duration of the Glacial epoch.

II. SOME MODIFICATIONS OF MY PREVIOUS VIEWS.

In the article already alluded to, on the "Relation of Land levation and Ice Accumulation" I attempted to reconcile the vo antagonistic views in regard to the attitude of land during the lacial epoch. According to some writers the land in high latitude gions was greatly *elevated;* according to others it was on the conary *depressed.* According to the one, the intense cold and ice ccumulation was the direct result of the elevation, and a subseuent depression produced a moderation of the climate and a ıelting and final disappearance of the ice; according to the other, ıe ice accumulation was not coincident with the elevation and, ıerefore, there must have been some other cause for the cold and e accumulation. In the paper referred to I showed that all the henomena might be satisfactorily explained by supposing that ıe elevation was the cause of the cold—the cold the cause of ıe ice accumulation—the weight of the accumulated ice the ause of the depression—the depression the cause of returning

[1] Origin of Transverse Mountain Valleys, Univ. Chronicle, Vol. I, No. 6, p. 179, 398.

warmth — the warmth the cause of the melting and retreat of the ice,and finally that the removal of the ice-load was the cause of the re-elevation to the present condition; but — and this is the distinctive feature of my view — that in all these cases *the effects lagged behind the causes.* I showed that this was so in all cases of accumulated effects, but would especially be true in this case. To illustrate these relations I used a diagram which I here pro-

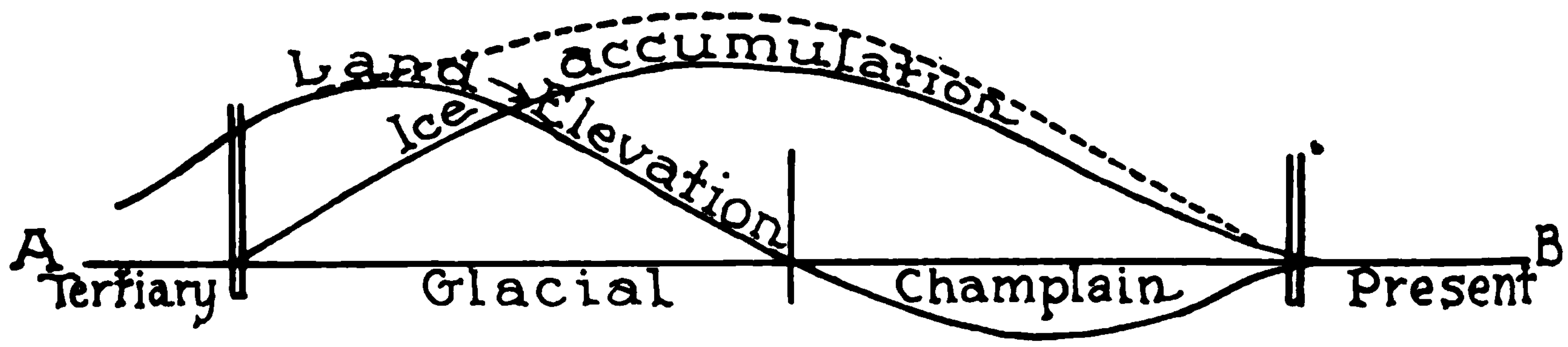


FIG. 1.— Diagram showing the relations of land elevation and ice accumulation during the Quaternary. *AB* — course of time and also the present status of earth crust. The dotted line shows elevation if it had not been interfered with by the ice-load.

duce. The legend will sufficiently explain it. By this view the Quaternary consists of two epochs, the Glacial and the Champlain, of nearly equal lengths. The one characterized by elevation and cold, the other by depression and warmth, but the extreme of ice accumulation lagged behind the extreme of elevation as seen in the figure.

I am more and more convinced that the principle of lagging is a true one and even more important than I at that time supposed. I now believe that I did not at that time make the lagging, especially in the matter of the accumulation of the ice-load, great enough. We must make a distinction in this regard between the intensity of the cold and the thickness of the accumulated ice. The cold probably responded somewhat promptly to the land elevation, but not so the ice accumulation. This was a very slow process and might lag to any degree behind the elevation and the cold. This we now proceed to show.

1. Snowfall depends on cold, but still more upon moisture.

ow there is nothing in the way of supposing—but on the conary much reason to believe—that the period of great elevation as one of comparative dryness and that the climate became ioister in the latter part when the elevation was not so great. his would make the ice accumulation lag behind the elevation nd the cold.

2. But again: We must, of course, make a wide distinction etween the annual snowfall and the rate of accumulation; for is latter is the result only of the annual *excess* of snowfall over aste by melting and evaporation, and this excess may be to any egree small.

3. As it is, the *thickness* and therefore the *weight* of the iow that we are here concerned with, it must be remembered gain that there is still another and much more important source f waste antagonizing local accumulation and therefore increase f thickness, viz., the run-off—not the run-off as water but as e by glacial motion. After a certain thickness is attained this in-off completely balances the annual excess over waste by vaporation and melting, and prevents, farther increase of thickess. This is the case now in all glacial regions. In the Alps, ie Himalayas, etc., there is no indefinite increase of thickness ecause the run-off by glacial motion completely balances the nnual excess. Similarly in Greenland, and the Antarctic connent although there is great excess of snowfall over waste y evaporation and melting, yet there is no increase in the iickness of the ice sheet because the excess is balanced by the in-off of the ice into the sea and the formation there of iceergs which are carried away by oceanic currents.

So also in Glacial times, after a certain thickness of snow had ccumulated on any given area—say the Canadian highlands—ie farther increase would be prevented, because balanced by ie ice-sheet motion in all directions. Any increase of thickess would require not only excess but *increase of excess* and ould be extremely slow because always kept in check by the icreased run-off.

To sum up: Suppose, then, the highlands about Hudson

Bay to have been the center of elevation, of ice accumulation and of radiating run-off: Suppose farther, that the elevation commenced about the end of the Pliocene and was the cause of the cold. Then considering the previous warmth of the Tertiary times, it is probable that the elevation would go on for a long time and reach a considerable degree before there would be any snowfall at all in this region, and still much longer time before there would be annual excess over waste by evaporation and melting, *i. e.*, before there would be *perpetual snow*. After perpetual snow was reached, under the effect of the ice-sheet motion tending ever to bring about equilibrium, the increase of the thickness of the ice sheet must have been extremely slow. In fact, it is evident that no such thickness as actually occurred could

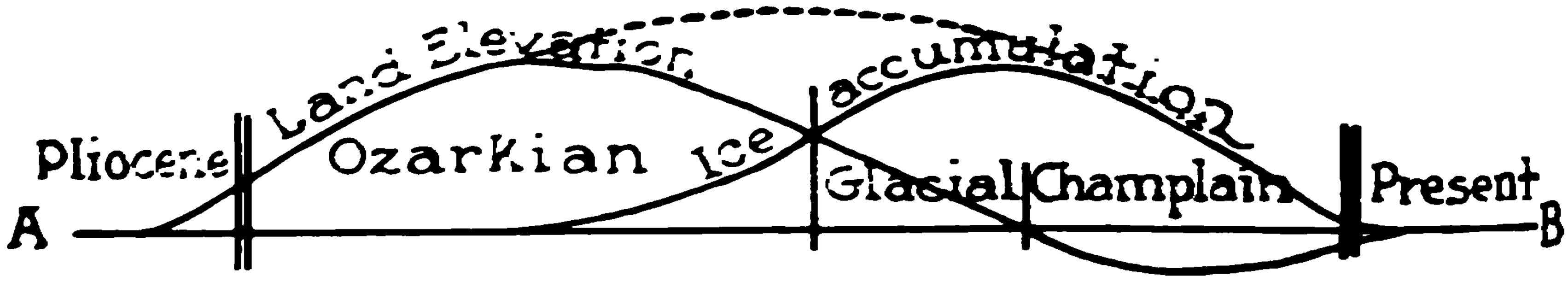


FIG. 2.—Diagram showing supposed relation of land elevation to ice accumulation, as now revised.

have been attained at all, but for the subsidence of the earth-crust under the weight of the ice. The increased thickness was conditioned upon and waited on the subsidence. I believe, therefore, that an increase of one inch per annum would be an extravagant estimate. At this rate it would take 150,000 years to make a thickness of 12,000 feet, which is the estimate of Dana. To this must be added the much greater time before the perpetual snow was formed at all.

Under the light of these estimates and especially of these new views of a long Ozarkian epoch preceding the glacial epoch, I would therefore modify my previous diagram, making the beginning of the ice accumulation much later and making both the Glacial and the Champlain much shorter than before, as shown in the revised diagram, Fig. 2. The greater distinctness of the Ozarkian from the Glacial is shown

III. SIGNIFICANCE OF THE OZARKIAN.

In my papers on *Critical Periods in the History of the Earth*, in 877 and in 1898[1] I try to show that there are periods of great nd widespread changes in the earth's crust, in climate, and in rganic forms. These I call "critical periods" and insist that hey separate the primary divisions of geological, time, viz., the *ras*. Being periods of great elevation and enlargement of coninents, they are to a great extent "lost intervals," *i. e.*, periods in which the usual record of stratified rocks and contained fossils s interrupted. The last of these was the Quaternary. The Ozarkian was largely a lost interval so far as stratified record is concerned.

Great cycles in the evolution of the earth.—Now an era, *i. e.*, he time from one critical period to another, must be regarded as one great cycle of widespread changes; during which, however, there may have been and indeed undoubtedly were, subordinate and more local cycles. Such a great cycle was the Paleozoic, very regular in its course in this country. Such another great cycle was the Mesozoic, but affected in this country with a well marked subordinate division at the end of the Jurassic. Still another such great cycle and again very regular in this country was the Cenozoic, and such another, I am convinced, is even now commencing. I have called it the Psychozoic.

I have supposed these to be cycles in the evolution of the earth. They are, therefore, such in every department alike. They are cycles in the evolution of earth-forms, *constructively*, *i. e.*, by *interior* forces in continental elevation and mountain formation. They are cycles in the evolution of earth-forms, *destructively*, *i. e.*, by *exterior* forces and erosive sculpturing. They are cycles of evolution in climatic conditions. And, finally, as the result of all these, they are also cycles in the evolution of organic forms and their geographical distribution. Most of these various forms of cyclical movement I have discussed in my previous papers, especially that in 1895. These, therefore, I merely

[1] Am. Jour., Vol. XIV, 99, 1877. Bull. Geol. Dept. Univ. Cal., Vol. I, 314, 1895.

mention and pass on. Some, however, I discuss fully now for the first time.

1. *Cycles of constructive forms.*—Of the four great kinds of earth movements treated of in my address as President of Geological Society of America, December 1896,[1] the greatest, viz., that by which are formed oceanic basins and continental arches, being determined by unequal radial contraction in the secular cooling of the earth, which in its turn is the result of an original heterogeneity in the density and especially in the conductivity of different parts of the earth, must have a cycle coëxtensive with the life of the earth itself, and therefore may be left out in this discussion. But superimposed on this greatest, there are other cycles of oscillations of the earth's crust over wide areas—of continental elevation and depression, accompanied with the formation of great mountain ranges. These are the cycles of next importance, and with which we are here concerned; for they determine all other cycles mentioned above, and therefore the occurrence of what I call critical periods. They are demonstrated by the widespread unconformities which occur at these times. Upon these, again, are superimposed still lesser cycles which, however, do not concern us here. I have sufficiently treated of these, both great and small, elsewhere, and therefore pass on.

2. *Cycles of climatic conditions.*—Coincidentally with the changes by continental elevation and depression with their attendant mountain-making, there have undoubtedly been concurrent changes in climatic conditions of many kinds, especially of temperature. These changes were, on the whole, probably gradual throughout the era, but culminate and oscillate in the critical period which closed it and constituted one of its most marked features. The two most conspicuous examples are those which occurred at the end of the Paleozoic and at the end of the Tertiary. The early Paleozoic was eminently an oceanic period. During the whole Paleozoic there was, in this country at least, a gradual elevation and enlargement of the continent.

[1] Bull. Geol. Soc. Am., Vol. VIII, p. 113, 1897.; Sci., Vol. V, p. 321, 1896.

slow at first, but rapidly increasing toward the end and culminating in the formation of the Appalachian chain. Concurrently with this there was, almost certainly, a gradual decrease of temperature rapidly culminating at the end in something approaching, at least, a true glacial epoch in the Permian. Similarly, there was probably, during the Tertiary, a gradual elevation and increase of land and diminution of temperature, culminating somewhat rapidly at its end, in the Ozarkian elevation and the Glacial ice sheet. Similar changes occurred at other critical periods, but less conspicuously.

I have been accustomed, in default of any other and more probable cause, to attribute the increase of cold directly to the increase of elevation, although admitting its possible insufficiency. It is this apparent insufficiency that constitutes the only justification of extra-terrestrial theories of Glacial climate, such as Croll's, etc. Recently Professor Chamberlin has contributed to the JOURNAL OF GEOLOGY[1] some admirable and suggestive speculations on the cause of these cycles of climate and of life. According to him, the continental elevation is not the direct, but mainly the *indirect* cause of cold, by the exhaustion of the supply of CO_2 in the air by continuous rock-decay during these land-periods. This supply is supposed to be restored from the interior of the earth through fissures, etc., produced by the commotions of these times. He, moreover, correlates these changes in elevation and in temperature in a most suggestive way with alternating richness and poverty of life and corresponding alternations of limestones and sandstones. I cannot, of course, dwell on these very suggestive views, but only draw attention to the fact that the cycles of which Professor Chamberlin speaks correspond to the *smaller* or subordinate cycles spoken of on pages 536 and 537, and *not* to the great cycles separated by critical periods and constituting eras. Nevertheless, there is no reason why similar causes acting with greater intensity at long intervals should not determine the greater cycles also.

3. *Cycles of geographic diversity of organic forms and of rates of*

[1] JOUR. GEOL., Vol. VI, pp. 597, 609, 1898.

evolution.—We have already explained in a previous paper[2] how during the course of a cycle, the geographical diversity of organic forms in isolated regions becomes greater and greater indefinitely as long as isolation continues, until finally synchronous correlation of strata in different regions becomes difficult or impossible. But that during critical periods (and to less degree at other times) there occur wide migrations and mingling of faunas and corresponding obliteration of geographical diversity, only to commence again with new isolations and a new geographical diversity increasing again with time. Thus there are alternations of increase and obliteration of faunal diversity. This idea has an important bearing on the doctrines of synchrony and homotaxy. At the beginning of a great cycle immediately after a critical period, geographical faunas commence, as it were, all abreast; synchrony and homotaxy are now in harmony. As time goes on, the newly mingled but re-isolated faunas develop in different directions and at different rates, become more and more divergent in character, and more and more different in grade of evolution. Synchrony and homotaxy become more and more discordant, until at the end of the cycle it becomes extremely difficult or even impossible to correlate strata of different countries synchronically. Then there comes another critical period of widespread oscillations of crust and readjustment to new conditions of equilibrium with accompanying oscillations of temperature and wide migrations of species and mingling of faunas and floras, hastening the steps of evolution everywhere, but obliterating geographical diversity, and, as it were, evening up again synchrony and homotaxy, only to commence a new cycle by re-isolation.

An attempt is made to roughly represent this process by a diagram (Fig. 3). In this diagram two cycles are represented. In the first, Europe is ahead, and increasingly so as the cycle goes on, and Australia is most lagging. In the second, North America is ahead. In each the divergence between synchrony (the full waving lines) and homotaxy (the horizontal dotted

[2] Bull. Geol. Dept. of Univ. of Cal., Vol. I, p. 314, 1895.

lines) becomes greater and greater until the end of the cycle, when there comes a critical period of wide migrations of species (represented by the horizontal arrows), a mingling of faunas, a fiercer struggle for life, together with the more active operation of other factors of evolution, and a consequent hastening of the steps of evolution everywhere, but especially in the lagging areas, to a more or less even general line. In the second cycle

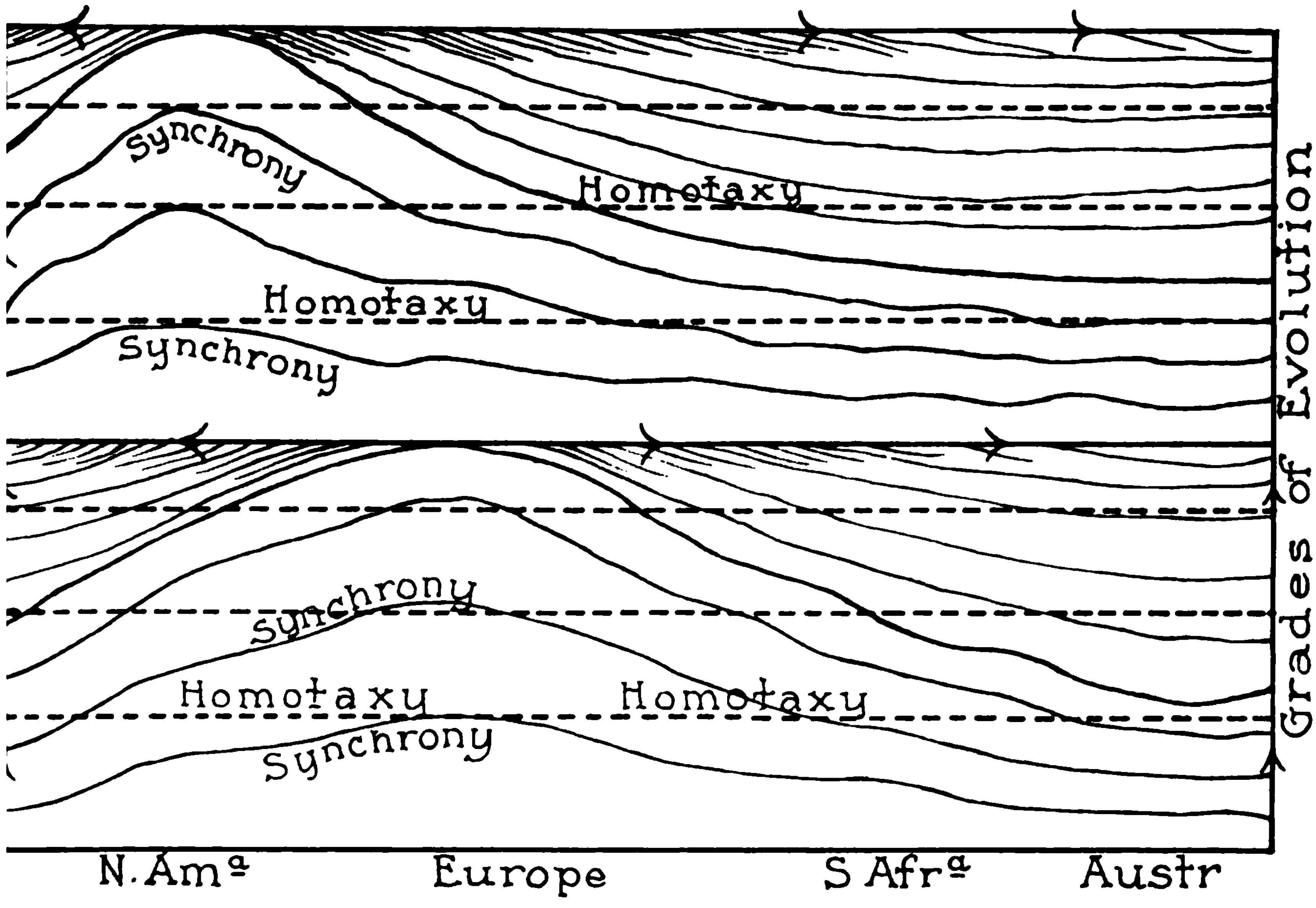


FIG. 3. Diagram showing the general relations of synchrony to homotaxy in geological times. Full lines represent the same time in different places (synchrony). Horizontal dotted lines represent equal stages in evolution (homotaxy).

the same process begins and progresses, except that now America is ahead, and increasingly so until the next crisis; when the synchronic lines are again evened up to parallelism with the homotaxic. If it were not for these occasional evening-ups a general geological history based on organic remains would be impossible.

The whole process may be likened to a long army line marching abreast over a broken country, led by officers, who may be compared to the dominant types. Soon the line

becomes irregular, and more and more so, until it is no longer discernible and all seems confusion. At certain intervals the leaders run along the lines hastening up the laggards until the line is re-formed. But the re-formed line again soon becomes irregular and falls into confusion, and is again re-formed, and so on.

Of course partial and more or less local readjustments of synchrony and homotaxy take place at intermediate times at the end of subordinate cycles. Sometimes in the general readjustment some locality may be left out. This is the case with Australia today. The last wide migrations and minglings of faunas and obliteration of geographical diversity, viz., that during the Quaternary, did not reach Australia, and therefore its fauna is still far behind in the race of evolution.

4. *Cycle of topographic forms by erosion.*—But there is still another cycle, and one with which we are especially concerned here, viz., the *cycle of erosion forms.* Every critical period is a time of the formation of great mountain ranges, and the crisis is usually named after the mountain range which forms its most conspicuous monument. Thus we have the Appalachian revolution, closing the Paleozoic; the Cordilleran, closing the Mesozoic. The pre-Cambrian crisis might well be called the Laurentian, and the one we are now specially dealing with, viz., the Quaternary or Ozarkian, might well be called the Basin Ranges revolution; for not only the basin ranges, but also the Sierra Nevada, the Coast Ranges of California, and the Mt. St. Elias Range of Alaska were either formed or else rejuvenated at that time.

Thus with every critical period there are new mountains formed and old ones rejuvenated; new lands formed by emergence of sea bottoms and old ones elevated or depressed. Thus new constructional forms are made and a new cycle of destructional or erosive forms inaugurated. These forms pass gradually through the stages so graphically described by Professor W. M. Davis and others, the final result being the so-called *peneplain.* Of course, there are subordinate, intermediate, and more local cycles; and therefore at the end of the great cycle

/e may have examples of both old and new topography. But 1 any case a critical period, being the beginning of a new great ycle, after such a period we have only or mainly new topogra- hy. This is the true and conclusive answer to Professor Tarr's bjection to Professor Davis' far-reaching deductions from the upposed discovery of the remnants of former peneplains. 'rofessor Tarr objects that if there be any such former pene- lains there ought to be peneplains formed now and in the pres- nt geological epoch—that the very foundation of geology as n inductive science consists in the use of causes and processes ow in operation as the basis of reasoning on phenomena of arlier times. Yes, *causes* and *processes* now in operation, but not *esults* and *forms* now existent and produced in the present poch. Causes and processes are constant, or nearly so, but esulting forms pass through a regular cycle of evolution- hanges. Now the *last cycle is just commenced.* We must wait t least a few millions of years before we can expect to find eneplains made out of the recently inaugurated and highly mphasized topographic forms. As a note of warning against asty generalizations Professor Tarr's paper cannot be too ighly commended. We are all too apt to be carried away by new idea. It is apt to become a fashion of thought for which ve are ever seeking confirmation; and in all complex and imper- ectly understood questions, what we seek earnestly for we are ery apt to find. It is possible, yea, it is probable, that the pene- lain idea has been overworked; that many of these ancient eneplains exist only in the fervid imagination of the too ardent eologist. Nevertheless, the principle is a true one and ndoubtedly a very fertile one. Geological history has hereto- ore been based almost wholly on the results of sedimentation. t is time that it should be based also, and equally, on the esults of erosion. These results may be more difficult of inter- retation, but difficulties ought only to stimulate investigation.

Is the Ozarkian Tertiary or Quaternary? Finally, we are now repared to return to the question of place of Ozarkian in the eological classification. After what has been said the answer

to this question is plain. Critical periods, as I have shown in previous papers, are the great landmarks separating the primary divisions of geological time—the eras. They are the comparatively fixed points between which we correlate periods as best we can by comparison. Now, if the Quaternary be indeed one of these and the last, then it is evident that the Ozarkian, being a time of great elevation and enlargement of continents and therefore a period of lost record, belongs par excellence to that period. It is the most important and characteristic part and the part which determined the whole succession of changes which inaugurated a new order of things, viz., Present, a new era, viz., the Psychozoic. The Tertiary was a period of comparative quiet, of gradual changes and abundant life. The Ozarkian commenced the series of evolutionary changes which inaugurated a new era and is the most characteristic and important epoch in the series.

That the Ozarkian belongs to the Quaternary, therefore, is certain. But the question still remains: to what era should we attach the Quaternary? Upham thinks that to be consistent I ought to put it in the Psychozoic because man was introduced in the Quaternary. On the contrary, I believe it should be allied with the Cenozoic. The Permian, too, is a transition, revolutionary, critical period between the Paleozoic and Mesozoic. But after much discussion it has been put with the Paleozoic. The Laramie is the transition, revolutionary, critical period between the Mesozoic and Cenozoic. Again, after long discussion, it has been put in the Mesozoic. So also, the Quaternary is the transition, revolutionary, critical period between the Cenozoic and Psychozoic. After some discussion it will [illegible] be put in the Cenozoic with the Tertiary. It is true that the [illegible] of the Psychozoic was [illegible] the Quaternary. But here, also, the analogy with [illegible] is good. A new era begins when the [illegible] new order is established. Reptiles were [illegible] Permian, but the reign of reptiles did not

[illegible]

begin until the Trias. Mammals were introduced in the Mesozoic, and even true mammals—eutheres—probably in the Laramie, but the reign of mammals did not begin until the Tertiary. So, also, man was introduced in the Quaternary and possibly even in the Pliocene, but for a long time he struggled doubtfully for mastery with the great beasts of that time. His supremacy was not established until after the Glacial epoch, *i. e.*, with the Psychozoic.

All I insist on, however, is that the Quaternary, wherever it is put, must all go together. It must not be split and its most characteristic part separated and put in the Tertiary. There may be, indeed, some good reasons for putting it *all* in the Tertiary, and analogy will bear this out. For example, it is customary to make three periods in the Carboniferous, viz., the Mississipian, the Coal Measures, and the Permian, but there is a growing tendency to unite the Permian with the Coal Measures as its uppermost transitional stage. Again, we may divide the Mesozoic into Triassic, Jura, Cretaceous, and Laramie, but it is more usual and probably best to unite the Laramie with the Cretaceous as its uppermost transitional stage. So, also, it is customary to divide the Cenozoic into two periods, Tertiary and Quaternary, but it may possibly be better to regard the Quaternary as the final transitional stage of the Tertiary, and thus to divide the Tertiary into four epochs, the Eocene, Miocene, Pliocene, and Pleistocene. All I insist on is that its most characteristic part and that which determined the whole series of changes characteristic of this time should not be separated from the rest.

A PLEA FOR PSYCHOZOIC AS AN ERA.

I again take occasion to insist on the present, as the beginning of a new era—the Psychozoic—separated from the Cenozoic by the last great critical period, the Quaternary. This must be so if the Quaternary be indeed a critical period comparable with those that separated the previous eras. That it is such is shown by the fact that it has all the characteristics of such periods. It is characterized (1) by widespread oscillations of

the earth's crust; (2) by the formation or rejuvenation of great mountain ranges; (3) by the formation of new constructional forms, and the inauguration of a new cycle of erosion forms; (4) by great climatic oscillations; (5) by wide migrations and minglings of faunas and floras, and fiercer struggle for life, and rapid changes of organic forms by wholesale destruction of old forms and evolution of new forms; (6) by more rapid steps of evolution, but a partial obliteration of previous geographic diversity, and the inauguration of a new cycle of increasing diversity; and (7) by the introduction of a new dominant type—man, who is now becoming more and more the great agent of change in the new era, especially in organic forms.

There can be no doubt that we are now in the midst of a change more sweeping and rapid than has ever before taken place in the history of the earth, but which we imperfectly appreciate because we are in the midst of it, and therefore lose the perspective. Why then should we hesitate to recognize that the present is indeed one of the prime divisions of geological time? It is more: it is that which alone gives significance to all that precedes.

JOSEPH LE CONTE.

AN ATTEMPT TO FRAME A WORKING HYPOTHESIS OF THE CAUSE OF GLACIAL PERIODS ON AN ATMOSPHERIC BASIS[1]

THERE are hypotheses and working hypotheses. The suggestion that the last glacial period was caused by the passage of the solar system through a cold region of space may be styled a hypothesis, but scarcely a working hypothesis in the geological sense, for it does not form the groundwork or incentive of geological inquiry. An astronomer might be moved to hunt for the cold spot, but it has no inspiration for the geologist. General suggestions of a possible cause do not reach the dignity of working hypotheses until they are given concrete form, are fitted in detail to the specific phenomena, and are made the agents of calling into play effective lines of research. The construction of a concrete working hypothesis suited to stimulate and guide investigation in a wholesome manner, and to take its place in competition with other hypotheses of like working potentialities, thereby inducing a more searching scrutiny of the phenomena and a more varied application of interpretations, represents the higher limit of present reasonable aspiration. It is much too ambitious to hope for a demonstrative solution of the origin of the earth's glacial periods by first intention in the present state of knowledge.

The hypothesis here offered is not worked out into satisfactory detail at all points, but it is hoped that it is sufficiently matured to justify a preliminary statement. In forming it, which has been the work of several years, I have found, or seemed to find, the phenomena of past glaciation intimately associated with a long chain of other phenomena to which at

[1] A brief statement of the salient features of this hypothesis was given in a paper entitled A Group of Hypotheses Bearing on Climatic Changes, JOUR. GEOL., Vol. V, pp. 653–683, Oct.–Nov. 1897. For earlier history see footnotes on pp. 654 and 681 of that paper.

first they appeared to have no relationship. This study led on and on until it became connected with many of the most fundamental problems of geology. When once an inquiry into the history of the atmosphere and its possible functions in the past was raised, there seemed no resting place until the origin of the atmosphere — and with it the origin of the earth — was reached. The inquiry raised profound skepticism regarding some of the most firmly accepted doctrines of the original state of the earth, its internal constitution, and the great dynamic forces that have controlled the larger phases of its history. A series of new, or partially new, hypotheses relative to these fundamental phenomena seemed to be necessary to fill out the group of alternative theories requisite to cover the ground of legitimate doubt based on specific reasons for doubt. In other papers I have given a partial expression to the hypotheses framed to cover these points.[1] The exposition of these has not in all cases been sufficiently ample to give them good working form, but has perhaps been sufficient to show their general relationship to an atmospheric hypothesis of glaciation.

The hypothesis here offered is confessedly connected in my own mind with these ulterior and more fundamental hypotheses, but it does not seem to me that it is necessarily so connected. To be sure, if it is assumed, following a prevalent custom of the past, that the original atmosphere was a vast gaseous envelope embracing essentially all the carbonic acid that is now locked up in limestone and other carbonates, and all that is represented by coal and other carbonaceous matter, and that the atmospheric history has been essentially a progressive depletion of this original supply, I do not see how the proposed hypothesis can be entertained, at least for the earlier glaciations. But if it be

[1] [illegible] Hypotheses Bearing on Climatic Changes, Jour. Geol., Vol. V, [illegible] Time Divisions and the Classification of Geologic History [illegible] A Systematic Source of Evolution of Provincial Faunas [illegible] The Influence of Great Epochs of Limestone Formation [illegible] Lord Kelvin's Address on the Age [illegible] Science, N. S., Vol. IX, No. 235, pp. [illegible]

assumed that as early as Paleozoic times the atmosphere had some such constitution as it possessed in later geological times, and that its history has been a contest between the agencies of atmospheric supply and the agencies of atmospheric depletion, and that the constitution of the atmosphere at any time has been dependent upon the relative rates of supply and depletion, then the hypothesis may be entertained quite independently of all views of the origin of the earth and the atmosphere and of internal dynamics.

Previons advocacy of an atmospheric hypothesis.—The general doctrine that the glacial periods may have been due to a change in the atmospheric content of carbon dioxide is not new. It was urged by Tyndall a half century ago and has been urged by others since. Recently it has been very effectively advocated by Dr. Arrhenius,[1] who has taken a great step in advance of his predecessors in reducing his conclusions to definite quantitative terms deduced from observational data.[2] The great labor involved in this and the specific results springing from it place his contribution on a much higher plane than the general suggestions of those who had preceded him. Valuable as these general suggestions were, they must still be regarded as falling much short of working hypotheses, since no attempt was made to show that changes in the content of carbon dioxide of such a degree as would be compatible with the continuity of life and with other limiting geological conditions were quantitatively competent to produce the effects assigned them; nor were modes of inquiry into this essential matter suggested. It is one thing to point out a theoretical *causa vera*, and quite another thing to give good reasons for believing that it is quantitatively sufficient, and to open lines of inquiry for demonstrating that it is so. This Dr. Arrhenius has done and apparently with great success. While his results are doubtless to be regarded as subject to modification when more full and exact data are at hand,

[1] On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground, by SVANTE ARRHENIUS, Phil. Mag., April 1896, pp. 237–276.

[2] See review of his paper in this number of the JOURNAL, p. 623.

it is apparent upon inspection that they can be very largely modified and still fall within the limits of the conditions of the case. This will perhaps appear more evident in the course of the subsequent discussion. In so far as the deductions of Arrhenius and the accompanying views of Professor Högbom[1] fail to definitely postulate operative geological agencies competent to produce the requisite variations in the constitution of the atmosphere, and to give reasons for believing that such agencies were in operation at the times requisite to produce the effects assigned them, they fall short of furnishing an ample working hypothesis from the geologist's point of view. This, of course, is the function of the geologist rather than the chemist and the physicist. Professor Högbom has made a valuable contribution to the general doctrine of consumption and supply.

To form a good working hypothesis in a geological sense, it is furthermore necessary to assign subsidiary agencies working in an oscillatory manner correspondent with the oscillations of glaciation now so well authenticated by observation.

Specific requisites of a working hypothesis.— It is obvious that it is necessary at the outset to assign agencies capable of reducing the amount of the carbon dioxide of the atmosphere at the time of the glaciations. If there were no other glaciation than that of the Pleistocene period, and if there were no kindred phenomena needing to be elucidated at the same time, it might be sufficient to point to the well-known abstraction of carbon dioxide from the atmosphere in the formation of limestones and carbonaceous deposits, and there rest the case, with the implication that further production of limestones and carbonaceous deposits would insure further glaciation, and that the permanent and final winter of the earth is at hand. A very slight computation of the rate at which carbon dioxide is now consumed is sufficient to show that an effective depletion of the atmosphere is near at hand unless there be sources of supply approximately equal to the depletion. But recent depletion touches only the

[1] SVENSK KEMISK TEDSKRIFT, Bd. VI, p. 169 (1894). Quoted in Dr. Arrhenius's paper, p. 269.

easier part of the problem. Whatever may be thought of the supposed signs of cold periods at other early periods, the evidences of glaciation in India, Australia and South Africa near the close of the Paleozoic era are so abundant, so specific, and so well attested, that they cannot be ignored, and any hypothesis that assumes to account for glacial periods must take serious cognizance of these and must meet the strenuous issues that spring from their early age and from the mildness of the periods following them. It seems to the writer almost equally necessary to take cognizance of the salt and gypsum deposits of various periods, which imply degrees of aridity in relatively high latitudes scarcely equaled at the present day. If the atmospheric line is followed, it seems necessary to postulate a reduction of carbon dioxide near the close of the Paleozoic era — to say nothing of other early times — so effectual as to produce glaciation between 20° and 35° latitude on both sides of the equator, a glaciation the deposits of which aggregate a greater thickness than those of Pleistocene times, and whose oscillations, marked by thick accumulations of coal, were even more remarkable than those of the Pleistocene glaciation. If a depletion of the carbon dioxide of the atmosphere sufficient to produce this glaciation at this relatively early stage in geological history is postulated, it is necessary to assign agencies for the reënrichment of the atmosphere in carbon dioxide to account for the mild climates in high latitudes in Jurassic, Cretaceous, and Tertiary times. In short, it is necessary to assign competent operative geological agencies which shall produce effective depletion alternating with effective reënrichment of the atmosphere from an early period in its history down to the present time. If the salt and gypsum deposits, and the prevailing red beds, with arkose elements, be regarded as the products of exceptional aridity, and if this be assigned to the localization and intensification of heat and moisture due to the removal of carbon dioxide, as subsequently set forth, it is necessary to multiply the oscillations from enrichment to depletion very notably, and to extend the alternating action at least as far back as the close of the Silurian period

when the great saline deposits of New York, Ontario, Ohio, Michigan and adjacent regions were laid down.

Primary assumptions. — (1) It is therefore assumed as the working basis of the hypothesis that the carbon dioxide of the Paleozoic atmosphere was at certain stages not essentially greater than it is today; that at the specific epochs of great saliferous deposition and of glaciation it was reduced to a quantity notably less than the present content, while at other and intervening stages its amount exceeded the present content by some multiple — these latter periods being those in which the wide extension of marine epicontinental life took place. For myself I am disposed to extend the assumption of a measurably limited atmosphere back to the very beginning. To this I am led in part by the conviction that the gravitation of the earth is incompetent to hold an atmosphere very greatly beyond the amount so assumed, and by the much more speculative consideration that the earth may have grown up by slow accretion rather than rapid concentration, and that hence the early development of the atmosphere was controlled by limitations much like those that have affected it in its later history. But, as already remarked, this assumption is not regarded as vital to the hypothesis. (2) Wrapped up in the foregoing postulate is an assumption of the essential correctness of the doctrine of Arrhenius that variations of the atmospheric carbon dioxide falling within limits compatible with life and with other geological phenomena, are competent to effectively change the thermal state of the atmosphere. This needs further statement.

The functions of carbon dioxide. — By the investigations of Tyndall,[1] Lecher and Pretner,[2] Keller,[3] Roentgen,[4] and Arrhenius,[5] it

[1] Heat as a Mode of Motion, 2d ed., pp. 345–346, 1862. Contrib. to Mol. Physics, pp. [illegible], 1882.

[2] Sitzungsberichte der Akad. der Wissenschaften in Wien (2), Vol. LXXXII, p. 851; Vol. LXXXIV, p. 52.

[3] [illegible], Vol. XXVIII, p. 100.

[4] Wiedemann's Annalen (2), Vol. XXIII, p. 1259.

[5] Phil. Mag., Vol. XLI, pp. 237–276.

A brief statement of the conclusions of these authors is given in the article of Mr. Tolman in this number, p. 5[illegible]. See also his review of Dr. Arrhenius, p. 323.

has been shown that the carbon dioxide and water vapor of the atmosphere have remarkable power of absorbing and temporarily retaining heat rays, while the oxygen, nitrogen, and argon of the atmosphere possess this power in a feeble degree only. It follows that the effect of the carbon dioxide and water vapor is to blanket the earth with a thermally absorbent envelope. Their absence would leave the surface of the earth essentially exposed to the free impact and free radiation of the solar rays, measurably, though of course not entirely, as if the earth were devoid of atmosphere. A reduction or an increase in these constituents would produce corresponding partial effects. The general results assignable to a greatly increased or a greatly reduced quantity of atmospheric carbon dioxide and water may be summarized as follows:[1]

a. An increase, by causing a larger absorption of the sun's radiant energy, raises the average temperature, while a reduction lowers it. The estimate of Dr. Arrhenius, based upon an elaborate mathematical discussion of the observations of Professor Langley, is that an increase of the carbon dioxide to the amount of two or three times the present content would elevate the average temperature 8° or 9° C. and would bring on a mild climate analagous to that which prevailed in the Middle Tertiary age.[2] On the other hand, a reduction of the quantity of carbon dioxide in the atmosphere to an amount ranging from 55 to 62 per cent. of the present content, would reduce the average temperature 4° or 5° C., which would bring on a glaciation comparable to that of the Pleistocene period.

The amount of moisture in the atmosphere, other things being equal, is directly dependent upon the temperature, and the temperature in turn is dependent upon the amount of moisture in the atmosphere. This reciprocal dependence renders the aqueous

[1] The action has two phases that in an exhaustive exposition would need separate statement, (1) the absorption of solar rays before they reach the earth, and (2) the absorption of the rays radiated by the earth. The latter have longer wave-lengths on the average and are relatively much more affected by the constitution of the atmosphere.

[2] Dr. Arrhenius, loc. cit.

vapor a vacillating factor subject to the control of any other agency which increases or decreases the atmospheric temperature. Whenever therefore an increase of carbon dioxide raises the temperature, it increases the quantity of water vapor and this by its thermal absorption further increases the temperature and calls forth more vapor and this action and reaction continue in diminishing force until an equilibrium is established. A decrease in carbon dioxide decreases the temperature and thus lessens the water vapor, and this further lowers the temperature and inaugurates a reversed series of actions and reactions. Fluctuation in the quantity of carbon dioxide therefore is attended not simply by its own individual effects, but by these auxiliary effects also. The carbon dioxide becomes therefore the determinative factor, and the question of the thermal absorption of the atmosphere may be discussed for convenience as though it were solely dependent upon the fluctuations in the content of this constituent, although this will not be strictly exhaustive.

b. A second effect of increase and decrease in the amount of atmospheric carbon dioxide is the equalization, on the one hand, of surface temperatures, or their differentiation on the other. The temperature of the surface of the earth varies with latitude, altitude, the distribution of land and water, day and night, the seasons, and some other elements that may here be neglected. It is postulated that an increase in the thermal absorption of the atmosphere *equalizes* the temperature, and tends to eliminate the variations attendant on these contingencies. Conversely, a reduction of thermal atmospheric absorption tends to *intensify* all of these variations. A secondary effect of intensification of differences of temperature is an increase of atmospheric movements in the effort to restore equilibrium. Increased atmospheric movements, which are necessarily convectional, carry the warmer air to the surface of the atmosphere, and facilitate the discharge of the heat and thus intensify the primary effect. In the case of a naked earth, the radiant energy of the sun falling directly upon the tropical belt is concentrated in space, and subject to the minimum reflection; in high latitudes, the rays

are spread over greater space, and are subject to greater relative reflection because of the low angle of incidence. In the case of an earth swathed in a thermally absorptive mantle, the direct equatorial ray is absorbed in traversing the atmosphere to a less extent than the ray of higher latitudes because it penetrates a less depth of atmosphere, while the amount of reflection from the atmosphere is small in both cases, so far as the transparent elements are concerned. In so far therefore as the temperature effects are dependent upon the absorption of the incoming rays, the greater depth of atmosphere penetrated in the higher latitudes makes important compensation for obliquity of incidence.

In the case of a naked earth, or an earth clothed with a non-absorptive atmosphere, the solar rays which are tangential to the polar regions have no heating influence upon the earth, while in the case of an earth clothed with an absorbent atmosphere, similar rays are partially absorbed, and serve to warm the earth. In the polar regions, therefore there is a very radical difference between the effects of an absorbent and a non-absorbent atmosphere. The same holds true of the heating effects of the morning and evening sun. With a non-absorbent atmosphere, the tangential morning and evening rays pass through and are lost; in a thermally absorbent atmosphere, they are effectually retained.

In so far as the incoming rays are absorbed in the atmosphere their immediate effects are chiefly felt in its upper strata and their influence upon the surface of the earth is lessened. This is due to the fact that the upper regions are penetrated by rays of all the various wave-lengths that emanate from the sun, while the lower portions are penetrated only by such rays as are left after the selective absorption of the upper atmosphere. The degree of this absorption of the rays of long wave-lengths is such that comparatively little further absorption takes place in the basal portion of the atmosphere, according to the interpretations of Arrhenius. One effect of increasing the absorptive capacity of the upper air by increasing the amount of carbonic acid is an increase in the elevation of the strata chiefly heated by the

incoming rays and the consequent reduction of the thermal gradient of a vertical column of the atmosphere. As a result there is less effective tendency to convection and less discharge of heat from the atmosphere.

In high latitudes, besides this effect, it is also to be noted that with an increase of the absorptive capacity of the upper atmosphere, rays that previously passed through the higher strata with little absorption are arrested and contribute heat to the upper air. The same is true of morning and evening rays at high elevations.

In the case of the outgoing rays, which are absorbed in much larger proportions than the incoming rays because they are more largely long-wave rays, the tables of Arrhenius[1] show that the absorption is augmented by increase of carbonic acid in greater proportions in high latitudes than in low; for example, the increase of temperature for three times the present content of carbonic acid is 21.5 per cent. greater between 60° and 70° N. latitude than at the equator. The maximum thermal effects also lie in higher latitudes for the summer months than for the winter months. ‹ On the other hand, when the carbonic acid is reduced to 0.67 of the present content, the maximum winter variation is felt between 30° and 40° N. latitude.› If the carbonic acid be further reduced, the maximum variation found by extrapolation falls at and below 30°, the latitude of the Carboniferous glaciation. It is not intended, however, to imply that this would be sufficient in itself to produce that glaciation.

An atmosphere having a relatively large percentage of carbon dioxide and water, *i. e.*, an absorptive atmosphere, has a higher heat content than a non-absorptive one, and its circulation in latitude more effectually equalizes the temperature with the same degree of movement.

Similar considerations are applicable to the effects of land and water areas. In so far as the atmosphere absorbs the incoming rays in passing through it, the amount that reaches the surface of the earth is reduced. To this extent the possibility of

[1] Loc. cit., p. 266.

differential effects between the sea and land is lessened. On the other hand, in the absence of absorptive and diffusive effects, the tropical rays fall with full intensity upon the surface. On the land they promptly heat the immediate surface, and the heat is as promptly radiated away. On the sea, neglecting reflection, they penetrate deeply into the water until they are absorbed. The upper layer of the sea is therefore heated to a notable depth, and radiates its heat away with relative slowness. The result is an intensification of the differences in average temperature of the land and the sea. This action is quite familiar, but perhaps not the point here urged—that this difference is dependent on the atmospheric effects upon the incoming as well as outgoing rays. If the atmosphere were so far robbed of its absorbent factors, carbon dioxide and water, as to give great intensity to this differential effect, the result might be an average temperature of the land below the freezing point, while that of the sea might be relatively warm. It seems clear that at some point short of an absolute thermal transparency a stage would be reached where the average temperature of the land would sink below zero, while yet the sea, barring convection in latitude, would retain a comparatively mild temperature. There would then apparently arise, even in low latitudes, the conditions of glaciation.

Without following out these lines into greater detail, the more pertinent deductions may be summed up in the following propositions: A reduction of the thermal absorption of the atmosphere would intensify the differences of temperatures between (1) the basal and the upper portions of the atmosphere; (2) low and high latitudes; (3) land and sea; (4) night and day; and (5) the seasons. In short, it would intensify temperature differences generally, and would lead to (1) greater local heat, as well as greater local cold; (2) to greater local dryness, as well as greater local moisture; (3) to more intense movements of the atmosphere in the endeavor to maintain equilibrium; and (4) to lower average temperature. The effect of reducing the absorbent factors is the intensification of differences.

On the other hand, an increase in the absorptive factors renders ineffectual, in a corresponding degree, the variations of altitude, of latitude, of land and sea, of day and night, and of the seasons, and conduces to an equable and mild temperature, to gentle and yet thermally effective circulation, and to higher average temperature. As Arrhenius has remarked, "The geographical, annual, and diurnal changes of temperature would be partly smoothed away if the quantity of carbonic acid was augmented. The reverse would be the case (at least to a latitude of 50° from the equator) if the carbonic acid diminished in amount."[1]

AGENCIES OF DEPLETION AND ENRICHMENT

It now becomes necessary to assign agencies capable of removing carbon dioxide from the atmosphere at a rate sufficiently above the normal rate of supply, at certain times, to produce glaciation; and on the other hand, capable of restoring it to the atmosphere at certain other times in sufficient amounts to produce mild climates.

These agencies on both sides belong to two classes, the permanent and the temporary, and the distinction has practical importance.

Sources of permanent loss.—Permanent depletion results from the consumption of carbon dioxide in the transformation of the silicates of the original earth, and of volcanic products into the carbonates of the secondary strata. It is fairly safe to assume that the original earth's surface was composed of material of the general class represented by the igneous rocks and the basement complex. These, it is needless to say, consist largely of silicates with which are associated certain quantities of certain gases to be considered more fully hereafter. These silicates, where exposed to the weathering action of the atmosphere, become decomposed and take the form of carbonates (with less quantities of sulphates, phosphates, etc.) and of residual silicates and oxides (kaolin, quartz, ferric oxides, etc.). Neglecting the minor transformations which do not concern us here, the operation may be

[1] Loc. cit., p. 268.

characterized as carbonation, and consists essentially of the substitution of carbonic acid for the silicic acids. The carbonic acid is derived, in the main, from the atmosphere. In their soluble condition, the carbonates so formed are largely bicarbonates. This is the only form in which calcium carbonate is appreciably soluble, and the same is true in a less degree of magnesium carbonate. The monocarbonates of potassium and sodium are highly soluble, but the bicarbonates also appear in solution. Practically the carbonates of these alkalis usually become changed into other salts (sulphates, chlorides, etc.) and the carbon dioxide that may have been temporarily locked up with them is set free by the change, or enters some other combination. The magnesium and calcium carbonates are also in part changed to other salts. But for the purposes of this discussion, which is concerned chiefly with the final issue and not with the transient stages of these compounds, it is sufficient to note that the chief result of the decomposition of the original silicates is the formation of calcium and magnesium carbonates, which are deposited as limestones and dolomites and thus lock up carbon dioxide at the expense of the atmosphere. The amount so taken from the air in the known geological periods has been variously estimated at from 20,000 to 200,000 times the present content; indeed estimates have gone beyond the last figure. When it is considered that 44 per cent. of all pure limestone and a higher per cent. of all pure dolomite is carbon dioxide, it is obvious that the total quantity is very large, and its computation is dependent upon the estimate of the total amount of limestone and dolomite in the crust of the earth.

A second source of permanent loss consists of the consumption of carbonic acid by plants and the fixation of the carbon in carbo-hydrates, hydro-carbons and other carbonaceous compounds which ultimately take the form of coals, bitumens, oil, gas, and perhaps most important of all, disseminated organic matter in the sedimentary series.

Exceptions.—Some hydro-carbons have probably been produced by inorganic action, notably those derived from carbides

(Moissan) formed within the earth and extruded from it. Some carbonates probably have been formed by carbonic acid contained within the rocks or extruded from the interior. In certain phases of the problem, deduction is to be made for such carbonaceous compounds and carbonates as are formed in the sea by marine plants and other agencies which derive their carbonic acid from the sea water; but in the general discussion of the question, the carbonic acid of the sea must be reckoned in with the carbonic acid of the air, for the two are in equilibrium and constitute essentially and potentially one body. The necessity for this assumption will be more obvious when we come to discuss the function of the ocean in influencing the constitution of the atmosphere.

Sources of permanent gain.—Over against these sources of secular loss there are certain sources of gain. If the assumption that the constitution of the atmosphere has varied through only moderate limits within the known ages be adopted, it is necessary to postulate sources of supply of a competency approximately equal to the sources of loss. The data for such postulation are exceedingly unsatisfactory and a function of the hypothesis should be to stimulate investigation in these lines which have been barely touched by serious inquiry.

a. Gain from the interior.—The crystalline rocks of the surface of the earth have been shown by the recent examinations of Tilden[1] to contain very notable quantities of gas, consisting of hydrogen in preponderance, carbon dioxide and carbon monoxide in large percentages, and nitrogen and marsh gas in small quantities, with water vapor, but with a practical absence of oxygen. Twenty-five analyses, including ancient and modern volcanic and even some metamorphic rocks, gave an average volume of gas equal to about four and a half times the volumes of the containing rocks. A computation on this basis shows that an atmosphere equivalent in mass to the present one would be contained in a very superficial rind of the earth, and that if this volume of

[1] On Gases Contained in Crystalline Rocks and Minerals: W. A. TILDEN, Chemical News, April 2, 1897.

included gases be constant for the whole body of the earth, it contains potentially a multitude of atmospheres.

It is a familiar fact that enormous quantities of gases are ejected from volcanoes during their active periods. It has been very generally assumed that these gases and vapors, among which steam vastly preponderates, have a surface origin, and there can be no doubt that this is true of some notable part; but, on the other hand, there is abundant ground for the belief that another notable part is brought from the interior and is a real contribution to the earth's atmosphere and hydrosphere. It may not be possible at present to demonstrate this, but inquiry in this direction is invited. There seem to be no means of estimating from present data even approximately the volume of gas which is given forth, but it is certainly large. There are grounds for believing that the gases of the interior escape by other than volcanic vents. The deep rending and sharp shock of the earth in seismic movements, the stresses and fissuring of readjustments, the disintegration of crystalline rocks, and the resources of slow diffusive penetration are among these. So far as the setting free of carbon dioxide by decomposition of the containing rock is concerned, it is to be noted that the chemical action which sets it free involves a consumption of carbon dioxide very greatly in excess of the amount liberated, so that, as computation will show, the total effect of the process is one of loss which the internal gases only very slightly modify. This, of course, is not true of mechanical disintegration.

b. Exterior sources of gain.—The meteorites which are constantly falling to the earth contain included gases, often in great volume. They also contain carbonaceous matter which is partially burned in passing through the air. The nature of the included gases is notably similar to those of the crystalline rocks, hydrogen and carbon dioxide being the leading constituents with nitrogen in very subordinate amount and free oxygen essentially absent.[1] Water vapor appears in both meteorites and

[1] See numerous papers of A. W. WRIGHT in Am. Jour. Sci., notably Gases contained in Meteorites, Am. Jour. Sci, 3d series, Vol. XII, No. 69, Sept. 1876.

crystalline rocks, but it is impossible to say how far it was absorbed from terrestrial sources. It has even been suggested that all the gases both of meteorites and of the crystalline rocks were simply absorbed from the air and not brought in from without; but their proportions are so different from those of the air that it would be necessary to assume an extraordinary selective power to make this possible; for oxygen must be wholly rejected as a gas; nitrogen, though greatly preponderant, must be almost neglected; carbon dioxide must be absorbed in great quantities relatively; carbon monoxide, though very rare in the atmosphere, must be taken in abundantly; while the hydrogen, which is scarcely detectable in the atmosphere, must be absorbed in superlative amounts. It is difficult to conceive how a meteorite passing rapidly through the air can have absorbed many times its volume of an element which does not appear in the air in detectable quantities. However, I am unable to say that the analyses were made sufficiently soon after the fall of the meteorites to make this point conclusive. But, at any rate, the hypothesis of selective absorption is confronted with grave difficulties and the alternate hypothesis that the gases are brought to the earth in the meteorites seems the more probable. The emanations from comets support the view that meteorites are charged with gases in extra-terrestrial regions. Here again inquiry is needed and experimental tests are obviously suggested.

If gases are brought in with meteorites, it is probable that independent molecules are flying through space and are caught up by the earth. The modern doctrine of molecular velocities, which holds that gases are liable to escape, and presumably are escaping constantly, from planetary bodies, carries the presumption that individual molecules are flying through space with some degree of frequency. Astronomical phenomena, to be sure, seem to indicate that the quantitative value of these cannot be very great, but as definite data are yet wanting and we are dealing with vast lapses of time and slow processes of depletion, making need for slow processes of accretion only, this agency may

deserve a place among the undetermined sources of atmospheric material.

It is among the possibilities that the sun itself may be a direct source of atmospheric feeding. The speed at which the solar prominences are projected from the sun has been observed to exceed the parabolic velocity of the sun;[1] that is, the rate of projection is such that if the outer atmosphere of the sun does not effectually interfere, the gases are shot away beyond even the sun's control. A much less speed could carry the gases to the earth, so that, unless the outer atmosphere of the sun interposes effectual barriers, it is not improbable that gases are thrown as far out as the orbit of the earth. The earth probably cannot hold hydrogen, the chief gas of these prominences, permanently as such, but it may do so when combined with oxygen. The shooting of solar hydrogen through our atmosphere would lead to the formation of water, because, even at ordinary temperatures, such of the molecules of oxygen and hydrogen as collided with the requisite velocity would enter into union. There seem therefore grounds for placing this among the possible but undetermined sources of supply for our atmosphere and hydrosphere. When the mystery of the zodiacal light and the gagenshein shall be solved, it is possible that demonstrative evidence of our relations to the extreme projections of the solar atmosphere may be available.

In the present state of extreme uncertainty relative to all these possible sources of supply, a hypothesis which necessarily involves them proceeds with uncertain steps and must perforce wait patiently for more definite determinations, but the pressing of a hypothesis which lays emphasis upon them is but giving effect to the fundamental mission of all working hypotheses.

VARYING RATES OF ACTION ✓

By the terms of the hypothesis the state of the atmosphere at any time is dependent upon the relative rates of loss and gain.

[1] The Story of the Sun, by Sir Robert Ball, pp. 185–188; The New Astronomy, Langley, p. 61.

It is of supreme importance therefore to consider irregularities in the action of the sources of loss and gain.

Varying rates of gain.—The constancy or irregularity of the sun's contribution—assuming it to make a recognizable contribution—is quite unknown. It would presumably be dependent upon the internal explosive action of the sun concerning which all thought is as yet highly speculative. So far as its relations to geological periods are concerned, it would probably be either an essentially constant factor or one which would not fall in systematically with any special phase of geological progress, and could not be regarded as a coöperative factor in any definite phase. It might be progressively increasing, as the sun concentrates, or progressively diminishing.

Much the same is to be said with regard to possible sources of supply from meteoric and similar extra-terrestrial sources.

The extrusion of gases and vapors from the interior has been presumably periodic, because the conditions of molten eruption and of mechanical disruption have probably been periodic rather than constant. No specific determination of the periodicity of volcanic action has yet been made out, but the testimony of present geological data is to the effect that vulcanism has been more frequent and intense at certain periods than at others. This is clearly true for individual grand divisions of the earth, and seems to be true of the earth at large, notwithstanding the fact that vulcanism was a more or less local phenomenon. While a definite periodicity, specifically connected with other phenomena, cannot now be affirmed, the tentative proposition that vulcanism has been more abundant in great periods of readjustment than in periods of quiescence may be entertained. The connection with those periods seems sometimes to have been very intimate and immediate, and at other times more remote. So far as disruption of the rocks constitutes a means of escape for internal gases, there should obviously be a close connection with periods of readjustment. In a rather general and uncertain way, then, it would seem necessary to assume, in a working hypothesis, that the enrichment of the atmosphere from internal

sources has proceeded more rapidly at or about the periods of crustal disturbance. This, as we shall see, coincides practically with the periods of depletion from atmospheric action on the surface, and hence, so far forth, the two processes tend to neutralize each other and preserve the constancy of the earth's atmosphere. The hypothesis must therefore recognize that it was only when one agency fell behind the other in its competency that its specific results became manifest, and then only by the difference in their respective effects.

Varying rates of loss.—The rate of chemical action of the atmosphere on the surface of the rocks is believed to have been intimately connected with the extent and height of the land area, considering the earth as a whole. There were qualifying conditions, as we shall see, but notwithstanding, this is regarded as an important law. It is made a fundamental postulate of the hypothesis, and the vitality of the hypothesis as a working instrument of investigation hangs very largely upon it. It is obvious that the greater the surface area of rock exposed to the effective action of the atmosphere, the more rapid will be the rate of disintegration, other things being equal, and the more rapid the consumption of carbon dioxide. [1]

The rate of carbonation of the rock is dependent upon elevation as well as superficial area. The disintegration of rock is the most active by far in the zone lying between the surface and the level of permanent underground water, technically the water table. It is in this zone that the atmosphere and the moisture of the earth combine to give the greatest chemical

[1] Oxygen is also consumed in the decomposition of average rock, but in less amount than carbonic acid, and as the amount of oxygen in the air is very much larger than that of carbon dioxide, the part consumed is far less critical. In an exhaustive study of the constitutional history of the atmosphere, the loss and gain of oxygen must be considered, and certain very interesting and important phases of atmospheric variation are probably connected with the production and consumption of the oxygen, but, as indicated, they are much less immediate and critical in the consideration of thermal problems with which our hypothesis is more especially concerned, and for the sake of simplicity the oxygenation of the rocks may be temporarily neglected; and for like reasons the many minor reactions may also be ignored and attention confined to the carbonation.

activity. It is established by the most ample observation in mining, that below the permanent water level disintegration has made slow progress compared with that in the zone above the water level. Now the thickness of the zone between the surface and the permanent water level is intimately dependent upon the general altitude. In a continent reduced approximately to base level, this zone is exceedingly thin. In a region much elevated and deeply dissected by erosion, the thickness of the zone is very much greater. As between a continent with an average elevation of 2000 feet, at the climax of dissection following a crustal readjustment, and a continent of similar area with an average elevation of 300 feet, during a period when it is approximately at base level, the average depth of the aërated zone above the water level, probably varies more nearly with the square of the elevation than as a direct multiple of it. It is improbable, however, that the chemical action is augmented at so great a ratio. Probably greater warmth and more abundant vegetation are correlated with the lower altitudes, and both these aid chemical action. This in turn is somewhat offset by the greater mechanical disaggregation which results from changes of temperature and from gravitative influence in the more elevated condition. Making all allowances that seem required for the offsetting factors, it would still appear that the elevated condition increases the activity of decomposition in a very notable degree.

Below the permanent water level, the advantage probably also lies greatly with the higher elevation. The action of surface water upon the deeper rock is dependent upon the unbalanced hydrostatic pressure which promotes underground circulation and forces the water through the crevices and pores of the rock. If the underground water stands near sea level, there is little unbalanced hydrostatic pressure to promote active circulation and thereby carry the surface waters, enriched with atmospheric gases, down into the lower strata and bring them into action. The atmospheric waters precipitated upon the surface run away chiefly at the surface, and fail of the contact necessary for action. On the other hand, in an elevated region

here is a potential hydrostatic pressure measured by the differ:nce of altitude of the surface of the ground water and the urface of the sea which tends to cause the waters to flow hrough the rock and thus find a tortuous way to the equilibrium of the sea level. A deep underground circulation is therefore a unction of high altitude, and, correlated with that circulation, s chemical activity proportionate to the enrichment of the surace waters with chemically active agencies, in the present nstance, carbon dioxide in particular. This deeper circulation, orrelated with hydrostatic pressure, is enhanced by the greater legree of fissuring of the rock which attends elevated tracts, for n the process of elevation, writhing and cracking are notable ncidents, and, in addition to this, the gravitative tensions which iecessarily attend an elevated position lend their aid in the proluction and opening of crevices. Precisely the opposite conlitions prevail at low levels. The protruding superficial portion of the land is the most fissured part and when it has been cut .way by erosion the basal remnant is normally less open to the enetration of water. It would appear from a consideration of these several associated influences that disintegration and lecomposition are facilitated by elevation in a very important legree.

If, therefore, there were times in the history of the earth vhen there were general readjustments of its bodily form to ccumulated internal stresses, resulting in extensive elevations, mbracing not only the formation of mountains and plateaus, ut the general warping outwards of the continental platforms, nd the bowing downwards of the ocean basins, attended by the vithdrawal of the sea, so that the land area was extended and, t the same time its average elevation increased, and a portion f it rent and crushed, it is believed that the carbonation of the ocks must have been accelerated by some notable multiplier nd that the rate of consumption of the carbon dioxide of the tmosphere must have been correspondingly promoted ; and his is made an important postulate of the hypothesis.

At least two periods of such very general and notable

elevation appear to be well authenticated by present geological data, imperfect as they are for certain quarters of the earth. These periods occurred near the close of the Paleozoic and of the Cenozoic eras respectively. Closely connected with these two periods are two well authenticated glacial periods.

If, on the other hand, there were periods of prolonged quiescence of the earth's body during which the lands were cut down well towards base level, they would be accompanied by a progressive slackening of the rate of disintegration, and a corresponding reduction in the rate of atmospheric loss of carbonic acid, giving opportunity for the agencies of repletion to overtake and surpass the agencies of depletion. It is believed that there was a series of such periods among which the Cretaceous is best authenticated.

During a prolonged period of relative quiescence the encroachment of the coast lines upon the land, if elevated, becomes notable. In addition to this, the material removed from the land and deposited in the sea raises the water level, and when the degradation is notable this rise amounts to an appreciable factor. This aids the coast action by lifting it above the restraining influences of its own products, which, by shoaling the water off shore, tend to break the force of wave action. The notion is also entertained that during periods of readjustment the continental masses are apt to be lifted beyond the plane of perfect isostatic equilibrium, and that there follows a tendency to slowly creep back into equilibrium, accompanied by a general tendency of the continental platform to flatten out under gravitative stress. The continental platforms are to be regarded as having elevations above the abysmal ocean bottom of perhaps 12,000 feet, and, as their average gravity is two and a half to three times that of the water which surrounds them, there remains a large excess of gravitative stress tending to cause the continents to spread laterally.

The combined effects of these agencies is a transgression of a thin edge of the sea upon the land. Now, such extensive transgression took place on all the great continents in the Upper

Cretaceous period, and this fact may be taken as indicating that the planation which reached so pronounced an expression on the American continent at that period affected nearly or quite all the continents in some similar measure. An inspection of the whole range of geological history shows periods of similar transgression accompanied by the development of luxurious and cosmopolitan marine faunas of the shallow-water type which in themselves imply the conditions here postulated.[1]

If this be a correct view it is obvious that at such periods the areas of land exposed to atmospheric action were notably reduced by sea encroachment, and that at the same time the lowness of the land greatly limited the depth of atmospheric activity by reducing the zone between the surface and the water-table and by reducing the hydrostatic penetration of surface waters. As already remarked, there is to be counted in offset probably warmer temperature, a higher degree of moisture, and a more abundant vegetation, but it is not believed that this approaches, even remotely, to a full offset to the reduction due to low elevation and reduced area.

If the foregoing views are correct there were certain periods in the history of the earth when carbonation proceeded with multiplied activity, separated by other periods during which its activity was greatly reduced. The intensification and the reduction differ by some notable multiplier of the average rate.

In working application, the hypothesis tentatively recognizes as periods of land extension attended by rapid carbon dioxide consumption, (1) the close of the Silurian and the opening of the Devonian, (2) the Permian and early Triassic, and (3) the Pliocene and Pleistocene. To this category may perhaps also belong, though the evidence at present is less adequate, (4) the early Cambrian, (5) the closing Ordovician and opening Silurian,

[1] For further statement of these views, see The Ulterior Basis of Time Divisions and the Classification of Geologic History, JOUR. GEOL., Vol. VI, No. 5, July–August, 1898, pp. 449–462; A Systematic Source of Evolution of Provincial Faunas, JOUR. GEOL., Vol. VI, No. 6, Sept.–Oct., 1898, pp. 597–608; The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere, *ibid.*, pp. 609–621.

(6) the close of the Jurassic and the opening of the Lower Cretaceous, and (7) the transition period between the Cretaceous and the Eocene. In these periods there are evidences of declared intensifications of climatic influence expressed in widespread and thick deposits of salt and gypsum and in great series of red sandstones and marls, and, in the two most notable cases, by pronounced glaciation in middle and low latitudes.

On the other hand, it regards the following as periods of sea extension attended by the active freeing of carbon dioxide through the agency of prolific lime-secreting life, as hereafter set forth: (1) the middle Ordovician, (2) the middle Silurian, (3) the sub-Carboniferous, (4) the late Jurassic, (5) the Upper Cretaceous, and (6), less notable, the later Eocene and earlier Miocene. During these periods there is evidence of extensive limestone deposition spreading out widely on the continental platforms, attended by very mild and equable climates very nearly uniform for all latitudes.

SOURCES OF TEMPORARY LOSS AND GAIN

The discussion has thus far taken note of the original carbonation of the silicates of crystalline rocks only. These crystalline rocks, according to Dr. Tillo,[1] occupy something over 20 per cent. of the surface of the land. There remains nearly 80 per cent. occupied by secondary rocks which now claim attention.

Sources of temporary loss—The function of the secondary deposits. —To a large extent the material of the secondary deposits underwent chemical decomposition and carbonation preliminary to its deposition, indeed as a prerequisite to its derivation. In so far as this process was incomplete in the earlier stages, it was continued during any subsequent state of exposure, but this action belongs under the preceding head of original carbonation.

In the erosion of tracts of secondary rocks the limestones and dolomites are dissolved and carried down to the sea essentially as bicarbonates. In the strata they existed as monocarbonates. Their solution involves the taking up of a second

[1] Berghaus Atlas.

quivalent of carbonic acid to render them bicarbonates, and his second equivalent is derived essentially from the atmosphere. 'here is herein a source of temporary loss, temporary because he second equivalent of carbon dioxide remains associated with he bases in the sea only until deposition takes place, when it is et free. It is to be noted that a second equivalent is also taken p in the formation of original carbonates if they are dissolved. \s the crystalline rocks occupy only a little more than 20 per ent. of the land surface and are probably not removed as fast s the secondary rocks, not more than about one fifth, probably iot more than one tenth, of the bicarbonating carbon dioxide is ssociated with original carbonation. The remaining four fifths ır more are occupied in bicarbonating and dissolving the calca-eous and magnesian portions of the secondary rocks. It follows hat the ratio of carbon dioxide now taken out of the atmosphere s second equivalent in any unit of time, to that taken out as irst equivalent, is probably fully five to one, and not unlikely as ıigh as ten to one. This ratio would not necessarily hold for ›ast periods, but in all those under consideration the second :quivalent was undoubtedly very much greater than the first.

Accepting, for the purposes of a rude estimate, the data of T. Mellard Reade,[1] the amount of carbon dioxide removed annually ›y original carbonation, reckoned by proportional area, is 270 nillion tons, the amount temporarily removed as the second :quivalent of the bicarbonates is 1350 million tons; the amount ;imply transferred from the land to the sea as the first equivalent ›f the carbonates previously formed is 1080 million tons; the otal mass taken from the atmosphere annually being therefore 1620 million tons, and the total mass removed to the sea 2700 nillion tons. Besides uncertainties in the original estimate of Reade, the first item is subject to correction (probably large) for he slower rate of disintegration of the crystalline rocks. This s, however, somewhat offset by weathering action on the sili-:ates that remain undecomposed in the secondary rocks, and on

[1] Addresses, Geol. Soc. of Liverpool, 1876 and 1884, quoted in Dana's Manual, ›. 191.

the late volcanics which are not all included in the 20 per cent of the land area reckoned as crystalline. The second item is subject to correction to the extent that the salts were normal carbonates and not bicarbonates.

Reciprocal sources of temporary gain.—The second equivalent of the carbonates in the ocean is subject to easy removal under suitable conditions, and reënriches the atmosphere by diffusion into it from the ocean. The conditions under which this is set free are of critical importance to our hypothesis. We have to consider (*a*) saturation, (*b*) chemical reactions and dissociations, and (*c*) organic action.

a. Absence of general saturation.— In the absence of other agencies of removal the accumulation of calcium bicarbonates in the ocean would go forward to the point of saturation, if there were a sufficient amount producible. It would then be deposited as limestone, and the second equivalent of the carbon dioxide would be set free. There is little reason to think, however, that general saturation has been reached during the known portion of the earth's history. In local basins subject to peculiar conditions, saturation certainly has been attained, as the marls of the great saliferous deposits testify. The present approach to oceanic saturation in calcium carbonate is apparently only about 40 per cent. If the ocean in former times had reached saturation in calcium carbonate and any notable precipitation had followed, the precipitate should appear as a distinctive constituent of the clastic deposits. While calcareous matter which might be so interpreted occurs in some of these deposits, there is a notable absence of anything of the kind in many others where it might be expected, and the general character of the sandstones and shales seems more concordant with the accepted view that they were laid down in waters that did not, except in special cases, directly deposit calcareous matter. In view of the probable presence of lime-secreting organisms, the problem is generally rather to account for the paucity of calcareous matter than its abundance in the clastic deposits. The explanation is doubtless found in the undersaturation of the sea water and its ability

to dissolve calcareous relics. This view is supported by the partially dissolved condition in which calcareous fossils are so commonly found in the sediments of practically all the ages. The inference, therefore, to be drawn from the character of the sediments, and from the partial solution of calcareous fossils, is that the ocean, as a whole, has not generally been saturated with calcium bicarbonate during its known history. Murray has made us aware that at the present time the greatest depths of the ocean dissolve calcareous relics so freely as to prevent their accumulation.

b. Inorganic chemical reactions.—Viewed comprehensively the sea water consists of such solutions as have been carried down from the land in past times, modified by concentration and deposition. No important constituent has been totally removed. The land and sea waters have therefore the same fundamental constitution, but the salts of the former enter the sea in a more dilute form and in different proportions from those contained in the latter. Aside from organic action, and from exceptional inorganic agents such as may arise from submarine volcanic action and like incidental sources, essentially all occasion for chemical reaction when land waters are added to sea waters, is limited to a readjustment of the equilibriums of the common constituents of the two commingling waters. Following the simple doctrines of the old familiar "chemistry of results," the addition of a dilute solution of salts of the alkalis and alkaline earths to a more concentrated but not saturated solution of the same salts would neither occasion precipitation nor the evolution of gas, for every acid is mated with a base, and all are much below the point of saturation. According to the old interpretation the bases of the sea salts are, in the main, mated to stronger acids than those of the land waters, and these combinations will not be changed on the entrance of the latter. So, also, the small amounts of strong acids of the land waters are already mated with the strong bases in the main, and largely form the same combinations as those of the sea waters. Such interchanges as follow involve a double reaction essentially without the freeing

of acid or base. Under the old method of interpretation the sea salts, according to Dittmar, consist of—

	Percentage	Total Tons
Sodium chloride	77.758	$35{,}990 \times 10^{12}$
Magnesium chloride	10.878	$5{,}034 \times 10^{12}$
Magnesium sulphate	4.737	$2{,}192 \times 10^{12}$
Calcium sulphate	3.600	$1{,}666 \times 10^{12}$
Potassium sulphate	2.465	$1{,}141 \times 10^{12}$
Calcium carbonate	0.345	160×10^{12}
Magnesium bromide	0.217	100×10^{12}
	100.000	$46{,}283 \times 10^{12}$

A rude average of the composition of land waters and of the amounts of salts carried to sea annually, founded on the estimates of T. Mellard Reade, is here given for comparison.

	Approx. percentage	Tons annually
Calcium carbonate	50	$2{,}700 \times 10^{6}$
Calcium sulphate	20	$1{,}080 \times 10^{6}$
Magnesium carbonate	4	216×10^{6}
Magnesium sulphate	4	216×10^{6}
Sodium chloride	4	216×10^{6}
Potassium and sodium, Sulphates and carbonates	6	324×10^{6}
Silica	7	378×10^{6}
Other substances	5	270×10^{6}
	100	$5{,}400 \times 10^{6}$

These tables do not embrace the second equivalent of carbonic acid.

From these data it appears that it would require only a little over eight and one half million years for the land waters to bring in a gross amount of salt equal to that of the ocean, but it would require very different periods to bring in the individual constituents. It would take 166 million years to bring down the sodium chloride, but only about 1.5 million years to bring down the calcium sulphate, and only about 60,000 years to bring down the calcium carbonate. It appears therefore that there must be agencies constantly removing the calcium carbonate and the calcium sulphate at relatively high rates. These particular figures are subject to all the uncertainties involved in

Reade's primary estimate, but they probably represent approximately the relative ratios, and show the general nature of the eliminations that are requisite to change accumulating land waters into sea waters.

While these general statements of the nature and limitations of chemical action, based on the more familiar doctrines of the older chemistry, are doubtless essentially true, the refinements of modern chemistry teach that there is an intricate series of dissociations and exchanges of acidic and basic factors, and of the various ions, in an effort to establish and maintain a new equilibrium between the salts, required by their new proportions and their new states of dilution. As the land waters contain a relatively large percentage of bicarbonates of calcium and magnesium, the readjustment affects these especially, with the result that probably a minor percentage of the second equivalent of carbon dioxide is set free. It seems necessary to state this with qualification on account of the extreme complexity of the reactions, and the incompleteness of existing data; but the Challenger, and similar investigations show that the quantity of second equivalent of carbon dioxide is less than sufficient to raise all of the carbonates into bicarbonates. This deficiency is apparently limited to 20 per cent. or less of the theoretical amount required. More rigorous experimental determination is, however, greatly needed.

It is probable that the second equivalent of the land waters is deficient in some like degree, but this has not been experimentally determined. If this be true, it must reduce the estimate of the carbon dioxide brought down to sea, and also the amount set free by dissociation. The total amount of carbon dioxide which may be supposed to be set free by inorganic reaction in the sea in its present state of concentration, is therefore probably much less than 20 per cent. It is obvious from the preceding considerations, and others that will follow, that to maintain the atmospheric status even approximately there must be a nearly or quite complete return of the second equivalent of carbon dioxide by some means. This is also implied by the fact that

the oceanic deposits are not bicarbonates in any notable degree. The chief agencies of this return are held to be organic, and will be considered presently.

The chief compounds of both the land and sea waters are sodium, potassium, magnesium and calcium chlorides and bromides; sodium, potassium, magnesium and calcium sulphates; sodium, potassium, magnesium and calcium carbonates and bicarbonates; in other words, every combination which may take place between the acids and bases involved. Besides these salts there are, theoretically at least, the several acids and bases and a complete series of ions as well. There is a continuous dissociation and reunion in the effort to maintain equilibrium. The extent of the dissociation is dependent, among other things, notably upon the degree of concentration of the solution and upon its temperature. In an especial degree the extent of the freeing of the second equivalent of carbon dioxide is believed to be dependent upon this dissociation as influenced by temperature, and it is thus a vital consideration in realizing the function performed by the ocean during glacial episodes when its temperature was greatly changed. This function is made the subject of a special study in the paper of Mr. Tolman in this number of the JOURNAL.[1]

Mr. Tolman's studies have been founded upon Dittmar's experiments, and seem to show that the amount of carbonic acid freed from the bicarbonates by dissociation is very sensibly influenced by such changes of temperature as are necessary, according to the deductions of Dr. Arrhenius, to produce extended glaciation, on the one hand, and a mild climate in the arctic regions, on the other. In this he finds support for the suggestion which I made in a previous paper[2] that the ocean during a glacial episode instead of resupplying the atmosphere, in the stress of its impoverishment, would withhold its carbon dioxide to a certain extent, and possibly even turn robber itself. On the other hand, when the temperature is rising after a glacial

[1] Pp. 585–618.

[2] A Group of Hypotheses Bearing on Climatic Changes, Vol. V, No. 7, 1897, p. 682.

episode, dissociation is promoted, and the ocean gives forth its carbon dioxide at an increased rate, and thereby assists in accelerating the amelioration of climate.

c. Organic action.—The elimination of the vastly preponderating percentage of calcium salts in the land waters, involving a reduction from 70 per cent. in these to less than 4 per cent. in sea waters, is assigned mainly to marine life. With the calcium sulphate we do not seem to be specially concerned here except so far as indirectly it may become involved in the reactions which eliminate the calcium carbonate. It would appear obvious, however, from the fact that its ratio is reduced from about 20 per cent. in the land waters to about 3.6 per cent. in the sea waters that it suffers much secular loss. The reduction of the calcium carbonate from about 50 per cent. in the land waters to about one third of 1 per cent. in the sea waters is a fact of prime importance.

The amplest and most familiar geological observation shows that the elimination takes place mainly as normal carbonate of lime in the form of shells and skeletal parts of various marine animals, and of some plants. The gross fact of observation is the disappearance of great quantities of calcium bicarbonate from the water, and its reappearance as the secretions of animals and plants in the form of normal carbonate. Whatever may be the specific steps involved in their life economies, it seems essentially immaterial to consider here whether the animals and plants take their lime directly from the calcium carbonate, and set its surplus carbonic acid free, or whether they take it from calcium sulphate, and by using carbonic acid, derived ultimately from the waters also, convert it into carbonate, setting free the sulphuric acid to attack in turn the calcium carbonate of the sea, and thus by circuitous process free its carbonic acid, or whether the procedure follows any other indirect course; for the final result, when balanced all around, seems to be essentially the same. It may even trench on the organic cycle without essentially changing the final result. The important thing to be observed is that the process is dependent upon sea life, and varies with its

activity. There is no free supply of any competent discharging agency independent of sea life.

Influence of temperature on sea life.—The amount of lime-secreting sea life is greatly influenced by the temperature of the sea and by favorable habitat. Lime-secreting sea life, both plant and animal, is greatly favored by high temperature and reduced by low. In support of this the following citations from the Challenger Report[1] and other sources may be offered, in which I have italicized the significant parts.

Species of life which secrete carbonate of lime are abundant in the warmer waters of the ocean. In the *tropical regions* especially there are massive species of [illegible] and other genera that make up a large part of some coral reefs and of the surrounding islands and shoals. [illegible] is probably the extreme limit in which any of these organisms live in the ocean.

[illegible] are especially developed in *equatorial* and *tropical regions*, and are rarely met with in regions where the temperature of the surface water falls below [illegible]. [illegible], while abundant in tropical waters, are found farther north and south than the [illegible]; they are present even where the temperature of the surface is as low as [illegible] [illegible] attain their greatest development in [illegible]. These organisms are absent or [illegible] in the pelagic [illegible] of the open ocean.

[illegible]

[illegible]

[illegible]

There are not more than twenty or twenty-two species of pelagic Foraminifera, yet so numerous are the individuals of the species that they usually make up over 90 per cent. of the carbonate of lime present in the calcareous oozes of the abysmal regions of the ocean. . . .

The bottom-loving Foraminifera—those belonging to the Benthos—*are more abundant in the shallow water*, than in the deep-sea deposits, and occasionally a single species may occur in such abundance in shallow depths in some regions as to make up the greater part of a deposit. . . .

The presence of large numbers of Pteropod and Heteropod shells indicates tropical or subtropical regions, and relatively shallow depths. Abundance of the shells of pelagic Forminifera indicates the same regions, but when found without the shells of pelagic mollusks they indicate a greater depth than when these latter are present. . . . . The presence or absence, and the size of Rhabdoliths, Coccoliths and Coccospheres *give important indications as to latitude and depth*—the first predominating in tropical regions, the two latter being better developed in temperate regions, and *all disappear from the deposits as the polar waters are approached.*

A large number of these pelagic mollusks (Pteropod and Heteropod) *secrete carbonate of lime shells, and this is especially the case in tropical waters.* In *polar* regions the place of the shelled species is taken, with the exception of one or two small species of Limacina, by a *shell-less species.* The shells of the tropical species make up a large part of some tropical and subtropical deposits from moderate depths, in which there is a relatively small quantity of land débris. *Like the pelagic Foraminifera these pelagic* Mollusca attain their greatest development in the warm oceanic currents, *and diminish both in the number of species and the size and mass of the shells as the colder currents of the polar regions are approached.*

Reef-forming corals are confined to waters which, through even the coldest month, have *a mean temperature not below 68° F.* Under the equator the surface waters in the hotter part of the ocean have the temperature of 85° F. in the Pacific, and 83° F. in the Atlantic. The range from 68° to 85° is, therefore, not too great for reef-making species.[1]

An isothermal line crossing the ocean where this winter temperature of the sea is experienced, one north of the equator, and another south, bending in its course toward or from the equator, wherever the marine currents change its position, will include all the growing reefs of the world; and the area of waters may be properly called the *coral-reef seas.* . . .

Over the sea thus limited coral reefs grow luxuriantly, yet in greatest profusion and widest variety through its hottest portions.[1]

I have found no specific statements relative to the dependence of common mollusks on temperature, but the enumeration of the

[1] DANA: Corals and Coralline Islands, p. 83.

species in different latitudes clearly indicates that they are less abundant in the arctic provinces than in the tropical, from which it may perhaps be safely inferred that the lime-secreting function of the mollusks is increased by warm temperature.

In the foregoing quotations references are made to the preference of certain forms for shallow waters. The great preponderance of lime-secreting species on the shoal areas—100 fathoms or less—is too familiar to need emphasis.

In other articles[1] I have endeavored to show that there were certain stages in the earth's history when the seas were extended widely over the continental platforms, affording conditions extremely favorable to the multiplication of lime-secreting shallow-water life. I endeavored to connect these, on an observational basis, with the great limestone-producing epochs of geological history and to show that these were correlated with genial climates over high and low latitudes alike. On the other hand, I endeavored to show that there were other periods during which the land area was increased and the sea restricted, resulting in a great reduction of this normal habitat of the chief lime-secreting forms of life. I endeavored to show that so far as the lime-secreting life is concerned, the freeing of carbonic acid was promoted during periods of extended seas and that it was retarded during periods of extended land. This holds good when considered simply from the standpoint of available area, but it becomes still more true if, as this hypothesis maintains, the extension of sea-area was correlated with favorable temperature, while the restriction of sea-area was correlated with adverse temperature. The only pelagic life that enters much into the problem is that which occupied the superficial waters of the open ocean. The area of this increased and diminished concurrently with the extension and contraction of the sea.

[1] A Systematic Source of Evolution of Provincial Faunas, JOUR. GEOL., Vol. VI, No. 6, pp. 597–608.

The Influence of Great Epochs of Limestone Formation upon the Constitution of the Atmosphere, JOUR. GEOL., Vol. VI, No. 6, pp. 609–621.

THE FORMATION OF ORGANIC COMPOUNDS AS AN AGENCY OF ENRICHMENT AND DEPLETION

The familiar fact that plants produce complex carbon compounds at the expense of the carbonic acid of the air, and that animals, aided by plants, by combustion, and by decay, decompose these compounds, and return a portion to the air as carbonic acid need not be dwelt upon. These reciprocal processes constitute a cycle which, in so far as it is mutually compensatory, affects the constitution of the atmosphere only in temporarily locking up carbon in the transient organic matter. The cycle, however, is not complete at any time, and has fallen far short of being complete at certain times. A portion of the carbon compounds are not reconverted into carbonic acid, and this residuum has been sealed up in the strata, and represents so much of depletion of the atmosphere. When this residuum was large there was a hastening of the process of robbing the atmosphere. When it was small it put less tax upon the agencies of supply. In its concrete application, the hypothesis recognizes one notable period of residual accumulation, the Coal Measures. Subordinately it recognizes others, as the Huronian and the late Cretaceous. Perhaps the Coal Measure period is the only one in which the excess of carbon composition over decomposition was so great as to seriously influence the constitution of the atmosphere, considered by itself alone, though this is open to question. A computation of the carbonic acid locked up in coal and similar carbonaceous deposits compared with that locked up in the limestones shows that the former is greatly inferior to the latter, from which it is inferred that the organic factor has been much the less influential in producing variations of atmospheric constitution, *per se*, than through its relations to the carbonates.

Respecting the organic cycle itself, it is obvious that when the sum total of vegetable and animal life increases, the amount of carbonic acid locked up in the living organisms is increased, and *vice versa*. The total mass of all the vegetable and animal living matter on the earth is some small fraction of the total

amount of free carbon dioxide. It does not seem possible now to arrive at any closely approximate estimate of this ratio. Johnson[1] expresses the belief that the growth of plants would exhaust the carbonic acid of the atmosphere in 100 years if there was no return. The average length of time during which plant products remain as living tissue is probably greater than one year, and much less than ten years, which would make the total amount of the carbonic acid so locked up a quite small per cent. of that in the air. The amount of carbon locked up in the tissue of marine life which probably was not embraced in Johnson's estimate, would somewhat notably increase the figure, but if oceanic life is considered, the free carbonic acid of the ocean must be considered also which would greatly reduce the ratio.

A study of the life of the geological periods seems to indicate that there were very notable fluctuations in the total mass of living matter. To be sure there was a reciprocal relation between the life of the land and that of the sea, so that when the latter was extended upon the continental platforms and greatly augmented, the former was contracted, but notwithstanding this it seems clear that the sum of life activity fluctuated notably during the ages. It is believed that on the whole it was greatest at the periods of sea extension and mild climates, and least at the times of disruption and climatic intensification. This factor then acted antithetically to the carbonic acid freeing previously noted, and, so far as it went, tended to offset its effects.

THE FUNCTION OF THE OCEAN AS AN ABSORBENT OF CARBON DIOXIDE

The atmosphere penetrates the ocean by simple diffusion according to the laws of gas diffusion, modified slightly by hydrostatic pressure, and this must be considered in close computations, but is too small a factor to seriously affect the larger issues.

[1] How Plants Feed, p. 47.

Absorption of carbonic acid.—Independently of this the ocean has a specific power of absorbing carbonic acid. It is important to note that this power of absorption is greatly affected by temperature, as shown by the following table of the variations for *pure* water:[1]

1	volume	of	water	at	0°	dissolves	1.7967	volumes	of	carbon	dioxide.
1	"	"	"	"	5°	"	1.4497	"	"	"	"
1	"	"	"	"	10°	"	1.1847	"	"	"	"
1	"	"	"	"	15°	"	1.0020	"	"	"	"
1	"	"	"	"	20°	"	0.9014	"	"	"	"

The precise rates of absorption for sea water are not accurately determined, and, indeed, are determinable with difficulty because, experimentally, they are complicated with the "loose" carbonic acid of the bicarbonates which is liable to be constantly freed by dissociation. The rates appear to be something less than those that obtain in pure water. Mr. Tolman has discussed this factor in his paper already referred to.

Release of absorbed carbonic acid.—Theoretically both the carbon dioxide diffused through the ocean and that dissolved in it should be in equilibrium with that of the air. Its quantity is dependent upon the temperature of the ocean and upon the partial pressure of the carbon dioxide of the air. Whenever the temperature of the ocean is raised a portion of its dissolved carbon dioxide is given forth. Whenever the partial pressure of the carbon dioxide of the air is reduced a portion of the free carbon dioxide in the ocean diffuses forth to reëstablish the equilibrium. The tendency to equilibrium is always present, though the constant variations of temperature and partial pressure prevent its complete realization at any particular time. If there were no counteracting influence the free carbon dioxide of the ocean would act as though it were a part of the air, and as the carbonic acid of the latter was consumed, that of the former would come forth into it.

But with loss of atmospheric carbon dioxide there is a reduction of temperature, and this increases the absorptive power of

[1] Treatise on Chemistry, Vol. I. ROSCOE and SCHORLEMMER, p. 724.

the ocean which then tends to prevent the escape of the carbonic acid. Low temperature is, therefore, antagonistic to atmospheric depletion. Mr. Tolman has attempted to ascertain the relative value of increased absorptive power and reduced partial pressure, and, though the data are insufficient for final conclusions, finds them about equal. The withdrawal of carbon dioxide from the air does not therefore call forth a proportionate amount of free carbonic acid from the sea. Indeed it calls forth so little that the rate of atmospheric depletion is probably not appreciably retarded by it.

Summary.—Before proceeding to make special application of the hypothesis to the recognized glacial periods it may be serviceable to bring together into briefer statement the fluctuating features of atmospheric gain and loss.

1. Of the agencies of original or permanent supply, the internal group have probably fluctuated in some rude proportion to the disruption of the crust of the earth; the external group are beyond tangible treatment, but for aught that appears may be regarded as essentially uniform.

2. Of the agencies of permanent depletion, the conversion of silicates into carbonates (the chief factor) is assumed to have fluctuated essentially with the extension and restriction of the land; the formation of carbonaceous deposits fluctuated with the well-known conditions that presided over coal accumulation.

The agencies of permanent supply and of permanent loss are both regarded as rather slow in action and as being on the whole mutually compensatory, and indeed as being in some degree self-regulative, since increase of supply naturally increases consumption and reduction of supply ultimately reduces the consumption; but these relations are believed to be subject to sufficient fluctuation to give a basis for pronounced climatic changes.

The sources of temporary supply and waste are much more rapid in action and apparently more intense and voluminous in results within any brief period.

3. The sources of temporary loss are: (*a*) the locking up of carbon dioxide in bicarbonates while in solution as their second

equivalent (the great factor); (*b*) the absorption of carbon dioxide in sea water; and (*c*) its consumption in forming organic matter.

The first and greatest of these is definitely connected with extension and elevation of the land, and the second is largely a sequel to it, dependent upon the temperatures it induces, while the third does not usually coöperate with these two, but rather, to the extent of its limited competency, offsets them.

2. The sources of temporary enrichment embrace: (*a*) the discharge of the second equivalent of carbon dioxide in the sea by life action (the great factor), and (*b*) by dissociation; (*c*) the diffusion into the air of carbonic acid absorbed in the sea water due to higher temperature antagonized by reduced partial pressure, and (*d*) the freeing of carbonic acid both in the air and the ocean by the decomposition of organic matter.

These sources of fluctuation are definitely correlated with the elevation and extension of the land, on the one hand, and the extension of the sea and the reduction of the land, on the other. During an extensive elevation of the land, silicates are converted into carbonates at an increased rate and the limestones and dolomites are dissolved and carried to the sea more rapidly, both processes involving an acceleration of the consumption of carbon dioxide. Correlated with this extension of the land is a reduction of the sea area attended especially by a lessening of the area of the continental shelves which are the habitat of the chief lime-secreting life, while the area available for pelagic surface life is also lessened. Reduction in the lime-secreting life retards the incidental process of freeing carbonic acid and returning it to the atmosphere. The result is a reduction of temperature which in turn increases the ability of the ocean to absorb carbon dioxide and reduces the dissociation of the second equivalent of carbon dioxide, thus further reducing the returning process and increasing the capacity of the ocean to hold carbon dioxide notwithstanding the reduction of the partial pressure in the atmosphere. The reciprocating processes are thus temporarily affected in opposite directions so as to conjoin their results.

In periods of sea extension and of land reduction (base-level periods in particular), the habitat of shallow water lime-secreting life is concurrently extended, giving to the agencies that set carbon dioxide free accelerated activity, which is further aided by the consequent rising temperature which reduces the absorptive power of the ocean and increases dissociation. At the same time, the area of the land being diminished, a low consumption of carbon dioxide both in original decomposition of the silicates and in the solution of the limestones and dolomites obtains. Thus the reciprocating agencies again conjoin, but now to increase the carbon dioxide of the air.

These are the great and essential factors. They are modified by several subordinate agencies already mentioned, but the quantitative effect of these is thought to be quite insufficient to prevent very notable fluctuations in the atmospheric constitution. As a result, it is postulated that geological history has been accentuated by an alternation of climatic episodes embracing, on the one hand, periods of mild, equable, moist climate nearly uniform for the whole globe; and on the other, periods when there were extremes of aridity and precipitation, and of heat and cold; these last denoted by deposits of salt and gypsum, of subaërial conglomerates, of red sandstones and shales, of arkose deposits, and occasionally by glaciation in low latitudes.

T. C. CHAMBERLIN.

[The continuation of this article in the next number will embrace a discussion of the application of the hypothesis to known glacial periods, and to the oscillations from glacial to interglacial epochs, together with the agencies of localization, and a suggestion regarding the superposed minor oscillations.]

THE CARBON DIOXIDE OF THE OCEAN AND ITS RELATIONS TO THE CARBON DIOXIDE OF THE ATMOSPHERE.[1]

—C. F. Tolman.—

OUTLINE.

. Introduction.

. Laws of dilute solutions
  1. Mass action.
  2. Dissociation.
  3. Heterogeneous equilibrium and the change in the solubility of one salt due to the presence of others.
  4. Hydrolitic dissociation.

. Solution of gases in pure water.
  1. Class I.
  2. Class II. } Physical solubility.
  3. Carbonic acid. } Chemical solubility.
  4. Amount of gases dissolved.

. Solution of gases in salt solutions.
  1. Class 1. Oxygen, Nitrogen, etc.
  2. Carbonic acid.

. The ocean salts.
  1. Amounts.
  2. Degree of dissociation.

. The ocean gases.
  1. Oxygen, nitrogen and argon.
  2. Carbon dioxide.
     1. Simple Solution.
     2. As $H_2 CO_3$.
     3. Modified by the ocean salts.
     4. Maximum amount held thus in the ocean under the laws of gas absorption.
     5. Ditto. As second equivalent of bicarbonate.

. Relation of the atmospheric and oceanic CO_2.
  1. CO_2 of the bicarbonates.
  2. Dissociation of the bicarbonates.
  3. Degree of dissociation as a function of temperature and pressure.

[1] Especial thanks are due to Dr. Chamberlin, Dr. Stieglitz and Dr. Lengfeld, of
e University of Chicago, for careful revision of this article and many valuable sug-
estions.

4. Effect of variation of pressure and temperature postulated by Dr. Arrhenius. (*a*) Upon bicarbonate in the waters of the temperate zone. (*b*) Upon bicarbonates in equatorial waters. (*c*) Upon bicarbonates in colder waters.
5. Changes in volume of the belts due to cold water advancing southward.
6. Conclusions.

THIS subject has come to have special importance on account of the investigations of Professor Arrhenius[1] and Dr. Chamberlin,[2] on the effects of the atmospheric CO_2 upon the climate of the earth. Some of the earlier important contributions on the subject are as follows:

Tyndall calculated from his experiments that the absorption of radiant heat by atmospheric CO_2 is eighty times that of the oxygen or nitrogen, and that water vapor has an absorbing capacity of ninety-two times that of oxygen or nitrogen.[3]

By repeating and extending Tyndall's experiments, Dr. Lecher and his colleague, Pretner, concluded that carbon dioxide is the only agent in absorbing the sun's heat, and maintaining the earth's temperature above that of space.[4]

Mr. J. S. Keeler criticised the above and stated that the heat is absorbed by carbon dioxide and some other agent; either water vapor or matter in suspension.[5]

Professor Röntgen showed that water vapor has a marked absorption band in the ultra red and, therefore, plays an important part in maintaining the present surface temperature of the earth.[6]

Paschen demonstrated that both these gases play important parts in the atmosphere's heat absorption, and that sometimes one, and sometimes the other is the predominant factor.[7]

[1] Phil. Mag., Vol. XLI, pp. 237–279.

[2] JOUR. GEOL., Vol. V, 1897, pp. 663–683. Also this No., pp. 545–584.

[3] Introduction of Chemical and Geological Essays, T. S. HUNT.

[4] Sitzungsberichte des Akad. der Wissenschaften d. Wien (2) Vol. LXXXII, p. 851 (2) Vol. LXXXVI, p. 52.

[5] Am. Jour. Sci. (3) Vol. XXVIII, p. 190.

[6] Poggendorf's Annalen (2) Vol. XXIII, p. 1259.

[7] Phil Mag., S. 5, Vol. XLI, No. 251, April 1896, p. 239.

The discovery that this constituent of the atmosphere is an important dynamic factor among geological agencies has led us to investigate the eighteen potential atmospheres of carbon dioxide in the ocean. This at once leads us to a consideration of the chemistry of the ocean, and here we find that the indefiniteness of our notions upon this subject is not so much due to lack of data, for that has been collected by individuals and by well equipped expeditions, as to erroneous conceptions of the relations and reactions that obtain between the several constituents of a mixed solution. Important investigations involving large outlays of time and money have been rendered nearly valueless, because they were based upon assumptions which were accepted without proof, and which are now known to be false. The importance of the first principles which govern solution and precipitation in such a solvent as water (and which have but recently been formulated) justify a review of some of them as an aid to the interpretation of the reactions taking place in that great laboratory the ocean.[1]

Mass action.[2]—It will be remembered that Berthollet in 1803 was the first to conceive of chemical reactions as governed by equilibrium, dependent both on the mass and the affinity of the constituents. The value of his discovery was not realized because he unfortunately did not believe chemical compounds to have definite compositions.

In 1864 Goldberg and Waage re-stated the law of mass action, which may be developed as follows. Let us consider any two substances, A and B uniting to form two other substances C and D.[3]

All simple reactions that have been carefully studied have been shown to be reversible, therefore, as soon as any of C and

[1] Complete discussion of the laws of dilute solution, etc., may be found in any of the up-to-date text-books on physical chemistry.

[2] W. NERNST: Theo. Chem., pp. 353-455, etc., 117-150. OSTWALD'S Outlines of Chemistry.

[3] GOLDBERG and WAAGE: Videnskabernes Selskabs Forhandlinger, 1864.

D is formed there will be a union of C and D to form A and B. This reversible reaction is expressed thus:[1]

$$A + B \rightleftarrows C + D.$$

Let the degrees of concentration of the active masses, *i. e.*, the masses in units volume of A, B, C and D be respectively p, q, p' and q'. The unit measure of concentration is the gr. equiv. per liter. Let K be the rate of combination of unit masses of A and B, and K′ that of C and D. Now the magnitude of the reaction of A upon B is evidently $K\,p\,q$ (for the number of impacts of A upon B depends directly on their concentration) and that of C and D is $K'\ p'\ q'$. Now when equilibrium is established, the reaction of A upon B = the reaction of C upon D or $K\,p\,q = K'\,p'\,q'$ (the law of mass action).

Dissociation.— From the study of electrolysis[2] of salts, Clausius was compelled to assume that at least a small portion of the salt was dissociated into its positive and negative ions, Na Cl, for instance, into the positive ion ($\overset{+}{Na}$) and the negative ion ($\overset{-}{Cl}$).

Arrhenius[3] found that the osmotic pressure of a dilute solution of a salt in water, is that which it should have if a large proportion of the molecules of the salt are split into two smaller molecules (Na Cl for instance, into Na and Cl) and also that this change in osmotic pressure is a function of the electric conductivity.. He was therefore compelled to conclude that practically all of the salt may be dissociated in very dilute solutions, but, in more concentrated solutions the proportion dissociated becomes smaller. It then became evident that this action is reversible and is expressed

$$\overset{+}{Na} + \overset{-}{Cl} \rightleftarrows Na\,Cl.$$

[1] A simple illustration of a reversible reaction is the evaporation of water in an enclosed dish. Particles of water leave the liquid to form the superincumbent layer of water gas. As soon as any of the gas is formed it in turn gives back water particles to the liquid. Equilibrium is established and there is apparently no farther evaporation when the number of particles given off by the liquid equals the number of particles returned by the gas.

[2] Ges. Abh. (sep. papers) II, 135, 1867.

[3] ZEITS: Phys. Chem., Vol. I, pp. 631 ff.

Then, according to the law of mass action—

$$K_1\, ab = K_2\, c$$

where a and b are the concentrations of the ions ($\overset{+}{Na}$ and $\overset{-}{Cl}$) and c of the dissociated salt.[1]

$$\frac{a\,b}{c} = \frac{K_2}{K_1} = K\,. \qquad (2)$$

This K is called the ionization or dissociation constant, and is a constant under constant temperature and pressure, but is different for each different salt.

Salts, strong acids and bases (hydrochloric acid, sodic hydrate, etc.) are the substances most dissociated, while the weaker acids and bases (acetic acid, ferric or ammonium hydrate, etc.) are dissociated to a less degree, *i. e.*, the constant K is smaller.

It follows directly from equation (2) that the more diluted the solution the more complete is the dissociation. If the strength of the solution is such that concentration a and b are each represented by 2 and c by 4; and then the concentration of all be decreased so that a and b become 1, we find by substitution in the equation (2) that c also must become 1, and the ratio of dissociated to undissociated or *molecular* salt, is 1 : 1 instead of 1 : 2.

Heterogeneous equilibrium.—We may have some undissolved substance (C) in contact with a saturated *molecular* solution (C_1) of the same substance which is dissociated, more or less, into its ions (A and B). The concentrations are a and b for the ions, c for the undissolved (solid) salt. and c_1 for the undissociated dissolved part of C. Equilibrium being established between the solid C and the molecular solution of the solid ($C \rightleftarrows C_1$), the equation is

$$\frac{c}{c_1} = K_1\,. \qquad (3)$$

But the concentration of a solid at given temperatures and pressures is a constant (its specific gravity) ($c = K_2$), therefore

[1] This simple formula is not strictly accurate in the case of electrolytic dissociation but is correct enough for our purpose.

$$c_1 = \frac{K_2}{K_1} = K_3 . \qquad (4)$$

Now the dissolved undissociated part of the salt dissociates into its ions

$$(C_1 \rightleftarrows A + B) \quad \text{or} \quad \frac{ab}{c_1} = K_4 \qquad (5)$$

but substituting from (4)

$$ab = K_3 K_4 = K. \qquad (6)$$

This K is called the constant of solubility, or the ion product. This is the law governing precipitation of electrolytes, and under it there are three cases.

(a) $ab > K$.
(b) $ab = K$.
(c) $ab < K$.

(a) If ab is greater than K the action goes $A + B \longrightarrow C_1$, and again $C_1 \longrightarrow C$, therefore we have precipitation.

(b) If $ab = K$, we have equilibrium, and neither precipitation nor solution takes place.

(c) If ab is less than K the action goes

$$C_1 \longrightarrow A + B \text{ and } C \longrightarrow C_1 ,$$

that is solution takes place.

Now, if we mix solutions of two or more salts, besides the undissociated salts which were present in the separate solutions in equilibrium with their respective dissociated ions, we will have in the mixture also the salts that can be formed by the union of the positive ion of each salt with the negative ion of each of the other salts. From the foregoing the following propositions are derived :

Proposition 1.—Mixed solutions of two or more salts will contain all the salts that can be made by the combination of the ions of the original salts together with the free ions.

Proposition 2.—Of all these salts that one will be precipitated first whose product of ionic concentration first exceeds its constant of solubility or ion product.

If a salt be added to a mixture of salts in solution, there is added not only the salt itself but its ions also. If one of the

salts of the original mixture have an ion in common with the new salt (as for instance Cl in Na Cl and KCl), then the product of the ionic concentration of each salt is increased. Now if, before mixing, this product for either salt nearly equaled its constant of solubility, the increase may be enough to bring about precipitation. If, for instance, to a solution of lead chloride, which is not altogether insoluble in water, is added a sufficiency of K Cl, this addition causes a precipitate of lead chloride, since the addition of the Cl ions of the potassium chloride causes the product $\dot{Pb} \times \dot{Cl}^2$ to be larger than K where $\dot{Pb}$ = concentration of lead ions, and $\dot{Cl}$ = concentration of chlorine ions.

If, however, the salt added has no ion in common with ions of the other salts, it will take away from the ions of all the salts to form some of all the undissociated salts that result from the combination of the two new ions with all the ions of the original salts, therefore the product of ionic concentration for all the salts is decreased, or, in other words, the solubilities of all the salts are increased. Hence,

Proposition 3.—In a mixture of salts those with a common ion increase the ionic concentration of each, aiding precipitation, and those without a common ion decrease ionic concentration of each, and retard precipitation, each increasing the solubility of the other.

Hydrolytic dissociation.—Water, which is one of the weakest of acids, is itself dissociated into hydrogen and hydroxyl ions ($H_2O \rightleftarrows H + OH$); but this takes place to a very slight extent only. Kohlrausch found that at 18° C. for water distilled in a vacuum there is less than one gram of hydrogen ions in two million liters of water,[1] and Ostwald, Arrhenius, and Weis, and Kohlrausch[2] in later experiments (see reference below), found about one-sixth of this dissociation by other methods. Of course these free ions will react with ions of the salts in

[1] W. NERNST: Theo. Chem., pp. 658–662.

[2] F. KOHLRAUSCH and AD. KEYDWEILLER, Zeits. f. Phys. Chem., XIV, pp. 317–330.

solution to form some undissociated acid and base ($Na\,Cl + HOH \rightleftharpoons NaOH + H\,Cl$). But since there is such a very small amount of free dissociated ions of water and the dissociation constants of sodic and hydrochloric acid are large, this action is very slight. However, the salts of the weakest acids and bases are affected more by the same amount of dissociated water than those of the stronger ones, because, as shown by equation (2), K is smaller, therefore a larger amount of the undissociated acid, or base, exists in proportion to the ions.

Water when heated becomes more dissociated, and therefore a stronger acid, and this fact is sometimes made use of in the analytical laboratory, and is an important factor determining the composition of minerals deposited from hot solutions.

Solutions of gases in pure water.—If a gas dissolves in a substance with which it is perfectly neutral, that is, if no chemical reaction takes place between the gas and the solvent, then the amount of the gas dissolved in the liquid at a given temperature varies directly with the gaseous pressure, or partial pressure, if there be more than one gas.

Now, if any gas were absolutely neutral to the solvent, and if on solution its molecule suffered no change in constitution, we should get the same amount of heat absorbed or given off in the solution that would be absorbed or radiated by the same amount of gas brought to the density of the dissolved gas.

But upon solution in water it is found that some gases suffer a larger heat change than can be explained by any mere physical change in volume, while others have the same or nearly the same change in temperature, as that calculated upon the assumption of simple physical absorption. It has been shown that the gases with this large heat change upon solution undergo besides physical diffusion, a chemical change, more or less extensive. Therefore, gases may be arranged in two classes. The first class is composed of those gases which have but a slight reaction with water, and are sparingly soluble in that menstruum, and the other, of those which have large coefficients of solubility and which react with water to form definite compounds.

Of the former, those found in the ocean are nitrogen, oxygen, argon, etc., and of the latter, none are found in appreciable quantities, but we may take ammonia as a good example. This last unites with water to form NH_4OH which compound is known to exist as such.[1] The behavior of carbon dioxide towards water places it between these two classes. It unites with water to form H_2CO_3. This acid has never been separated as such, but doubtless exists.[2] This action does not give such a large coefficient of solubility as is characteristic of the gases of the second class.

The solution, then, of oxygen, hydrogen and argon, etc., is simple diffusion due to the attraction between the molecules of the solvent and those of the gas, while the solution of CO_2 in pure water includes (1) a diffusion of the gas molecules between water molecules and (2) a chemical reaction between the gas and water molecules to form carbonic acid.

Bunsen[3] has determined the solubility of the carbon dioxide for different temperatures as follows:

Solubility of CO_2 in H_2O, 1 vol. H_2O at t degrees and 760 mm. pressure dissolves V vols. CO_2 gas reduced to 0° C. and 760 ^{mm} pressure.

t° C.	V.	t° C.	V.	t° C.	V.
0	1.7967	7	1.3339	14	1.0321
1	1.7207	8	1.2809	15	1.0020
2	1.6481	9	1.2311	16	0.9753
3	1.5787	10	1.1847	17	0.9519
4	1.5126	11	1.1416	18	0.9318
5	1.4497	12	1.1018	19	0.9150
6	1.3901	13	1.0653	20	0.9014

In the above table the solubility is determined for pure CO_2 unmixed with other gases under 760 ^{mm} pressure. For low pressures the solution of the gas is proportional to the pressure or the partial pressure of the CO_2.

[1] PROFESSOR MALLET, Am. Chem. Jour., Vol. XIX, pp. 804–809.

[2] DAMMER, Anorg. Chem. II, 1, p. 871.

BUNSEN'S Gasometry, pp. 287, 128, 152.

The atmosphere, of course, is not pure CO_2, but a mixture of gases in the following proportions: Oxygen, 20.9 vol.; nitrogen, 79.1 vol., of which 01.18 per cent. belongs to that group of gases called argon,[1] CO_2 .03 vol.

At any given temperature the amount of the atmospheric gas dissolved in pure water is the product of the amount dissolved under 760^{mm} pressure of the pure gas by the partial pressure of gas in the air. This holds for the carbon dioxide in spite of the chemical reaction $CO_2 + H_2O \rightleftarrows H_2CO_3$. This may be seen as follows:

Let a, b, and c be the concentrations respectively of CO_2, H_2O, and H_2CO_3, therefore

$$\frac{ab}{c} = K_1,$$

but the water is so greatly in excess that its concentration, b, can be considered as a constant (K_2) or

$$\frac{a}{c} = \frac{K_1}{K_2} = K.$$

Therefore the amount H_2CO_3 $[c]$ varies directly with the amount CO_2 $[a]$ dissolved, and this is proportional to the partial pressure of the gas. Making the calculations from Dittmar's tables, we find that one liter of pure water at 15° C. dissolved from the atmosphere $.32^{cc}$ of CO_2, 7.2^{cc} of oxygen, and 13.2^{cc} of argon and nitrogen.[2]

The absorption of gases in salt solutions.—The researches of J. Setchenow[3] show us that a gas dissolved in salt solution obeys the same laws as if the salt were not present, if there is no chemical reaction between the gas, the salt, and the solvent. In this case, however, the attractive power between the molecules of the solvent and the gas is partially satisfied by the salt mole-

[1] Chem. News, 72 p. 308. Comptes Rendus de l'Academie des Sciences, CXXI, p. 605.

[2] Challenger Reports, Vol. I, pp. 167-168.

[3] Ann. de Chemie: pp. 226-270.

cules. From some of his tables we find that for a solution of the strength of the oceanic brine the diminution of the solubility for gases of this class is somewhere near 20 per cent. (*loc. cit.* pp. 245-259).

If, however, there is a chemical reaction between the gas and the salt, the solubility is increased by so much. Oxygen, nitrogen, and argon do not react with the salts of the ocean, but CO_2 does. The carbonic acid dissociates into its ions, and these ions react with the ions of the salts to form small quantities of undissociated compounds. This reaction has an appreciable effect only where the original salt is formed from weak acids and bases. From Mr. Setchenow's tables[1] for Na Cl solution of the strength of the sea water we gather that this increase for CO_2 would not be over 20 per cent. of that dissolved by pure water (.3^{cc} per liter, a quantity wholly negligible).

The ocean salts.[2]—The average temperature of the surface of the ocean is about 15° C.

The proportion of the different salts in the ocean, Professor Dittmar finds to be wonderfully constant for all parts of the sea water. He gives the following analysis for the salt:

Cl	55.292%
Br	.1884
SO_3	6.410
CO_2	.152
CaO	1.676
MgO	6.200
K_2O	1.332
Na_2O	41.234
Basic O (equivalent to Hologen)	−12.493
	100

This table we have recalculated for the percentages of the ions according to modern usage, and in order to facilitate subsequent discussion, as follows:

[1] Loc. cit., p. 246.

[2] Phys. Chem. Chall. Exp., Vol. I. Narrative of the Cruise of H. M. S. Challenger, 1885; Ency. Brit. XXI, pp. 611 to 614.

(Cl)	55.292%
(Br)	.188
(SO_4)	7.692
(CO_3)	.207
(Na)	30.593
(K)	1.105
(Mg)	3.725
(Ca)	1.197
	99.999

While the average constitution of the salts remains a constant, the salinity of the ocean is variable. Averaging 327 analyses, it is found that the average amount of salt is 34.7 grams per kilogram sea water, or taking the average specific gravity of the ocean as 1.026, about 35.6 grams per liter.

Applying this to the second table, we find that the total number of grams of the different ions per liter is as follows:

(Cl)	19.68
(Br)	0.07
(SO_4)	2.74
(CO_3)	0.08
(Na)	10.89
(K)	0.4
(Mg)	1.33
(Ca)	0.43
	35.69

Dividing by the equivalent weights, we find the relative strength of the ions per liter to be as follows, where the normal solution (one which contains as many grams per liter as the equivalent weight of the substance) is taken as unity.

Relative strength per liter

(Cl)	0.55 N. sol.
(Br)	0.0009 "
(SO_4)	0.057 "
(CO_3	0.0027 "
(Na)	0.47 "
(K)	0.01 "
(Mg)	0.112 "
(Ca)	0.022 "

Dividing the relative strength of the bivelant ions by 2, we find the relative number of ions.

Relative No. of ions

(Cl)	5500
(Br)	9
(SO_4)	285
(CO_3)	13
(Na)	4700
(K)	100
(Mg)	560
(Ca)	110

In the light of the previous discussion, we see that there must be sixteen different salts and eight different ions in the solution, under the supposition that the salts with bivalent ions dissociate completely into their metal and acid ions, and always neglecting the subordinate elements, such as strontium, iodine, gold, etc. Since, however, in a solution as strong as the sea water, there are two reactions in the dissociation of the salts having one bivalent ion, viz.:

$$Na_2SO_4 \rightleftarrows (\overset{+}{Na}) + (\overset{+}{Na}) + (\overset{=}{SO_4})$$
$$Na_2SO_4 \rightleftarrows (\overset{+}{Na}) + (Na\overset{-}{S}O_4)$$

there are also these extra ions, viz., ($Na\ SO_4$), of the bivalent acids and bases. Also instead of simply the salt of the radical CO_3 (normal carbonate) we have both the bicarbonate of the acid radical ($H\ CO_3$) and the acid radical itself.

From the propositions of the theory of dilute solutions it is possible to develop equations whose solutions will give the proportions of the various undissociated salts and of the free ions, but these computations would be of little value because of their complexity, and because the ocean water is too strong a solution for a numerical application of the equations developed for dilute solutions.

However, assuming that the constant K is of the same order of value for all the salts, and that the concentration of the free ions may be expressed by the relative number of ions calculated under the assumption that the salt is completely dissociated (see table p. 596), and neglecting the presence of the bicarbonate ion, we see that the relative amount of the undissociated salts will be expressed roughly by the products of the concentration of their respective radicals, and, therefore (from table p. 597) 1) Na Cl, 2) Mg Cl_2, 3) Na SO_4 exist in molecular form in greatest quantity, the rest following in about the order:

4)	$CaCl_2$
5)	K_2Cl
6)	$MgSO_4$
7)	Na_2CO_3
8)	NaBr
9)	$CaSO_4$
10)	K_2SO_4
11)	$MgCO_3$
12)	$MgBr_2$
13)	$CaCO_3$
14)	K_2CO_2
15)	$CaBr_2$
16)	KBr

If we examine the following table of Kohlrausch for K Cl and apply it to all the salts of the ocean, comparing the strengths of the oceanic solutions with the strengths of the K Cl solutions given in the table, we can form an approximate idea of the proportions of the molecular or undissociated salts to their respective free ions.[1]

N.	Per cent. dissociated molecules
1.	.75
.5	.78
.1	.86
,01	.94
.001	.98
.0001	.99

Under N is the strength of the solution where the normal solution is taken as unity.

From the above table and the one on p. 597 we conclude that somewhere about 80 per cent. of the sodium chloride is dissociated into its ions. We cannot judge so well about the sodium sulphate or magnesium chloride, but they also have some considerable amount of molecular salt, possibly more than of the sodium chloride. The potassium chloride is somewhere around 90 per cent. dissociated, and the potassium bromide, the last of the series, is practically completely dissociated.

The ocean gases.—The gases found dissolved in the ocean

[1] NERNST: Theo. Chem., p. 314.

water are nitrogen, oxygen, argon, and carbon dioxide. The nitrogen, argon, and oxygen are absorbed into the ocean directly from the air. Since the ocean is very generally agitated into waves, we may suppose that the gases dissolved in the outer portion of the surface water are in direct equilibrium with those of the air. The surface waters are being saturated with gas at temperatures varying with the daily and seasonal changes. Therefore, if there is no depletion or increase of these gases due to chemical or organic agencies we may assume roughly that the ocean, on the average, contains these gases in a proportion which may be calculated from the coefficients of absorption for the average temperature of the surface of the sea, which we assume to be 15° C. Therefore, to find the average amount of nitrogen, argon, and oxygen dissolved in the ocean we must determine their respective coefficients of absorption for sea water. From the remarks on the effect of salts on the solution of gases we should expect that the salt water would dissolve a little less of the above-mentioned gases than fresh water, because (1) salts in solution decrease the solubility of gases, and (2) because none of the gases react chemically with the ocean salts.

The following table, which is taken from a larger table of Dittmar, shows that these theoretical conclusions are correct:

cc AIR DISSOLVED PER LITER.[1]

	Pure water	Sea water
−5°	.....	27.27
0°	29.54	23.78
5°	26.09	21.08
10°	23.37	18.92
15°	21.16	17.17
20°	19.33	15.72
25°	17.80	14.44
30°	16.49	13.44
35°	15.36	12.53
40°	14.37	.....
45°	13.50	.....
50°	12.73	.....

[1] Loc. cit., pp. 172 and 175.

Taking, therefore, the coefficient of absorption for sea water as given by Dittmar[1], we find that at 15° C. the sea water dissolves 5.83^{cc} of oxygen and 11.34^{cc} of nitrogen and argon, which is less than shown by the figures given on page 594 for the absortion of pure water. We find on comparing these figures with the average of the gases as found in the Challenger analyses that the amount of the nitrogen and argon is near the amount calculated for the temperature of the water at the time it was collected, as we might expect in view of the mixing, etc., it undergoes. The oxygen, however, is always low, as it is used up in the oxidation of the organic matter in the ocean. It is almost up to the calculated amount in the surface water but a very large deficit in the deeper water. We may suppose, then, that the above figure for nitrogen and argon is approximately correct, but that the oxygen figure is considerably too high.

It is evident that we have a very different case to deal with in the solution of the CO_2 in the ocean. We have already found three ways in which the gas is held in solution. (1) Simple physical absorption; (2) united with the water to form (H_2CO_3); (3) held by equilibrium reactions with the salt ions. The total that can be held in these three ways at atmospheric partial pressure of the gas and at the average temperature of 15° is about 0.3^{cc} of CO_2 per liter of sea water.

Now, under the assumption that the partial pressure of the CO_2 increases with the depth of the ocean; and that the rate of this increase obeys the same laws as the increase of atmospheric pressure with the depth of the atmosphere, and, taking the average depth of the ocean at the large figure of three miles, we find a formula developed by Professor Woodward[2] that the pressure at that depth is 4.4 that at sea level. Also assuming that *all* the ocean is at a temperature of 0° C. (instead of only the portion at great depths) we find as a maximum estimate the ocean cannot hold over 2.4^{cc} CO_2 per liter dissolved as a gas,

[1] Loc. cit., p. 139.

[2] Communicated in a letter to Dr. Chamberlin.

according to the laws of gas absorption; this it is to be noted, under the unrealizable conditions of a uniform temperature of 0° C. and an average depth of three miles. But Mr. Buchanan found that on boiling, sea water gives an average 45^{mg} or 23^{cc} CO_2 per liter, or ten times the greatest amount the ocean could hold as a gas under more favorable conditions than those of the present time. Mr. Jacobson found 90^{mg} upon distilling the water to dryness. Mr. Buchanan thought that this great excess of CO_2 over that which could remain in solution under atmospheric pressure of CO_2 must be held in some sort of loose combination with one of the salts, and he decided upon the sulphates as the retaining agent. Such a misinterpretation, of course, might be expected at that time from the imperfect knowledge of the nature of the solutions. Before determining the free CO_2, therefore, he precipitated the sulphate with barium chloride, and unfortunately he must have obtained a mixture of $Ba\,SO_4$ and $Ba\,CO_3$, so that his numerous determinations are all probably somewhat too small.

But in spite of this his analyses show that the ocean contains about eighteen times the CO_2 of the atmosphere. Now, bearing in mind Professor Arrhenius' statement, "that to lower the temperature of the temperate region 5°, and bring on glaciation, the CO_2 of the atmosphere needs to be diminished to from 62 per cent. to 55 per cent. of its present value,"[1] the following questions suggest themselves:

1. How is the excess of the CO_2 found in the ocean at the present time held in solution?

2. Is it in equilibrium with that of the air?

3. If so, what proportion of the ocean gas will be brought out into the air by a diminution of the partial pressure of the CO_2 to an amount from 62 per cent. to 55 per cent. of its present value?

4. How much will the consequent fall of temperature increase the ocean's capacity for CO_2?

5. What is the relation between these two?

[1] Loc. cit., pp. 237–279.

In its immediate action, the ocean certainly has a moderating effect upon the temperature of the land. The great amount of heat necessary to raise the temperature of the water one degree, together with its vast evaporating surface, distributes the warmth received during the day over the night, much of the excess of the heat of summer throughout the winter, and the great downpour of radiant energy upon the tropics over the temperate and frigid zones. The question then arises: In the greater cycles of the variation of the earth's climate (whether dependent directly or only in part upon the fluctuations of the carbon dioxide content of the atmosphere) does the ocean still play the beneficent rôle of protector against the advances of the greater winters, furnishing the atmosphere some of its enormous supply of CO_2 as a blanket against the cold? Or, does the increasing cold cause the ocean, like a selfish monster, to keep a more grasping hold on the precious gas as the need of it becomes more imperative?

1. Besides the CO_2 which may be absorbed by the ocean from the air, it receives the gas (1) from the respiration of aquatic animals (2) from the decomposition of organic matter (3) from the interior of the earth through springs, etc., and (4) from the bicarbonates brought in by the rivers.

We find from analyses of the water of the principal rivers[1] of Europe, that about 60 per cent. of the entire mineral content of the river water is calcium carbonate dissolved as calcium bicarbonate. This calcium bicarbonate then is the great source of the extra carbon dioxide of the ocean. When this bicarbonate mixes with the ocean it is no longer strictly speaking, calcium bicarbonate, but mostly bicarbonate ions in equilibrium with small amounts of sodium, magnesium, calcium and potassium bicarbonates.

2. The various bicarbonates have been subject to numerous investigations since the researches of H. Rose[2] in 1835. These contributions show that sodium, potassium, ammonium, and

[1] BISCHOF, Chemical and Physical Geology, Vol. I, pp. 76, 77.

[2] Journal für Praktische Chemie, Neue Folge 10, 1879, pp. 417–444. Zeits. für Anorg. Chemie., Vol. XVII, pp. 170–204.

magnesium bicarbonates, partially dissociate at ordinary temperatures into the normal carbonate, giving out CO_2. Treadwell and Reuter have shown in the latest and most complete research on the subject (see reference above) that when calcium carbonate is dissolved under different partial pressures of CO_2, that the proportion of calcium to carbon dioxide, indicates that practically a pure bicarbonate, and not a mixture of bicarbonate and carbonate, is present in the solution.

The difference between the sodium, magnesium, etc., bicarbonates on the one hand, and the calcium bicarbonate on the other is seen from the following: (1) For the dissociation of magnesium bicarbonate we have in a saturated solution,

$$Mg(HCO_3)_2 \rightleftharpoons MgCO_3 + H_2CO_3 .$$

We have seen that the H_2CO_3 is directly in equilibrium with the CO_2 in the air; therefore at a given temperature, the degree of dissociation depends upon the partial pressure of the CO_2 in air. With variations of temperature, the colder the water, the larger is the portion of bicarbonate present, and therefore, the larger is the proportion of carbon dioxide in the ocean to that in the air. (2) For calcium bicarbonate we have:

$$Ca(HCO_3)_2 \rightleftharpoons CaCO_3 + H_2CO_3 .$$

But $CaCO_3$ is very slightly soluble, and therefore practically a constant for a *saturated* solution. Therefore, we do not have a mixture of bicarbonate and appreciable quantities of the carbonate, but the salt in solution is nearly all bicarbonate, and by lessening the partial pressure of the CO_2, $CaCO_3$ is precipitated from the saturated solution and the bicarbonate decreases. However, this difference between $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$ which Treadwell has emphasized, only holds for saturated solutions. It is evident that for an under-saturated solution of $Ca(HCO_3)_2$ we may have a larger proportion of normal carbonate than in the saturated solution and still no precipitation. Also, in ocean water (see p. 591), the numerous different salts tend to increase the solubility of the normal

carbonate, and allow perhaps a somewhat greater dissociation of the bicarbonate into carbonate. The bicarbonate in the ocean is, as shown above, not calcium bicarbonate, but bicarbonate of all the bases in solution, so that Treadwell and Reuter's investigations upon *pure* calcium bicarbonate in *saturated solution* cannot be taken to prove that the bicarbonates of the unsaturated sea water cannot be dissociated.

As direct evidence that the ocean is not saturated with calcium acid carbonate, we find (1) of the many hundred bottles of the Challenger's samples of sea water, from all depths and collected at all temperatures, kept several years, only one or two showed deposit of lime.[1] (2) Seashells from the bottom of the Pacific show corrosion and resolution.[2] Pteropod shells and foraminifera tests are slowly dissolved as they sink. The Pteropod shells are not found below fifteen hundred fathoms, and two thousand eight hundred fathoms is the limit for the globigerina ooze.[3] (3) Thoulet found by actual experiment that sea water will dissolve calcium carbonate from shells, corals, etc.[4] (4) Usiglio, studying the evaporation of the Mediterranean water at Cette, found that no precipitate was formed until the specific gravity of the sea water increased from 1.02, the specific gravity of the unevaporated water, to 1.0503 when the first precipitation begins, composed largely of calcium carbonate with ferric oxide.[5]

DEGREE OF BICARBONATE DISSOCIATION.

From twenty-seven analyses by Jacobson, we find an average of 91.4^{mg} per liter of free CO_2, and 120^{mg} CO_2 in the normal carbonate, or the bicarbonate is so dissociated that 25 per cent. of its second equivalent of CO_2 is lacking.[6]

[1] Loc. cit., p. 221.

[2] JOUR. GEOL., Vol. I, p. 504.

[3] Loc. cit., p. 221.

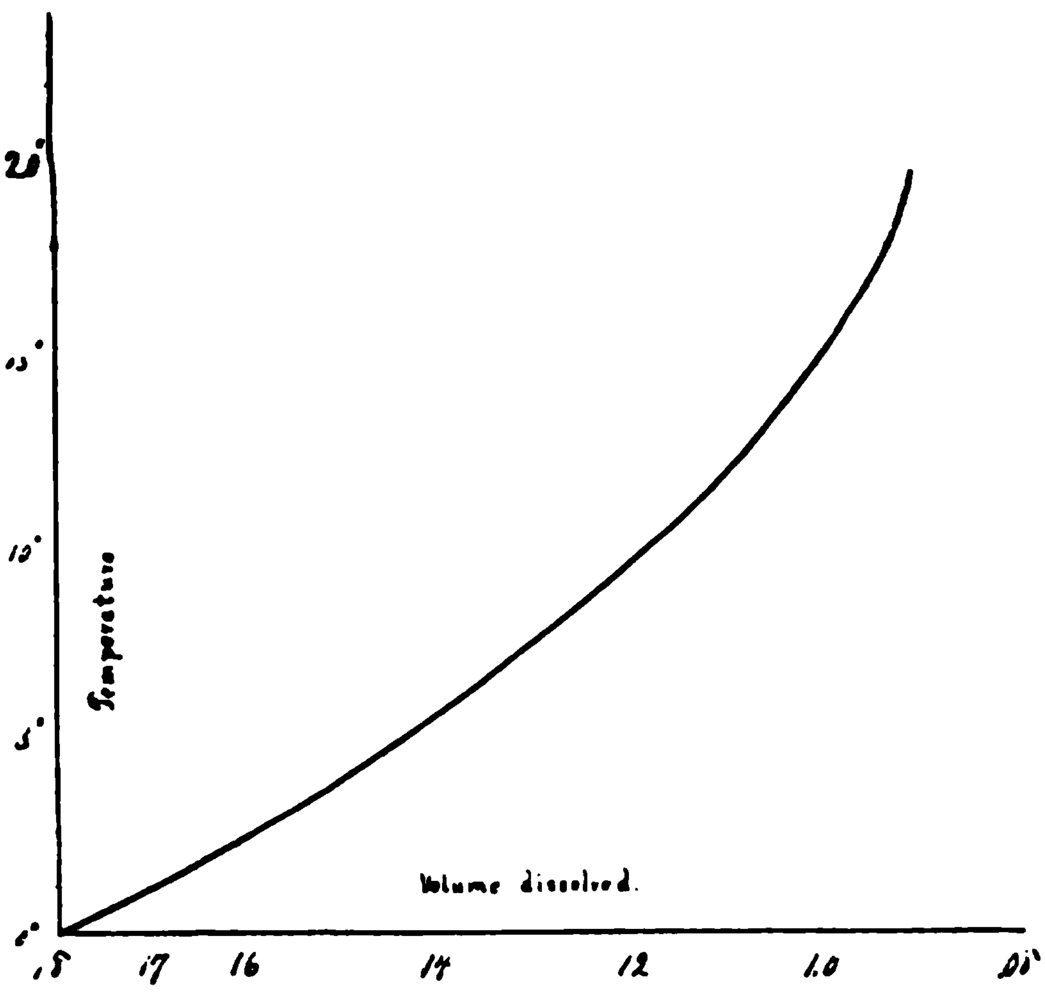
[4] Comptes Rendus, Vol. CVIII, p. 753.

[5] Encyl. Brit., Vol. XXI, p. 229.

[6] Uber die Luft des Meerwassers Ann. der Chemie und Pharm., Vol. CLXVII (1873), pp. 1–38.

From several hundred determinations of Buchanan, we strike an average of 45^{mg} free CO_2 per liter, to 53.4^{mg} CO_2 per liter of the *first* equivalent, *i. e.*, only 84 per cent. of the second equivalent is found in the ocean. Mr. Jacobson's analyses show a larger per cent. of the carbonates than were found in the Challenger's samples, which might be expected, as Jacobson's were collected only from the North Sea into which flow the great lime-bearing rivers of northwestern Europe.

To prove positively that the ocean bicarbonate dissociates into carbonate and free CO_2, Professor Ditmar shook in the air



FIGS. 1 and 2 represent respectively the effect of temperature on the solubility of CO_2 in pure water, and upon the dissociation of Na H CO_3.

FIG. 1 is taken from table on page 593 and under 760 mm pressure CO_2. The temperature is recorded on the ordinate, and on the abscissa are the volumes of CO_2 absorbed, compared with the volume of water in which it is dissolved.

a sample of sea water, that had an excess of CO_2, and found that CO_2 was given off, and that the ratio of the two equivalents was 100:84 at 13° C., exactly the same, it happens, as we found from averaging Buchanan's analysis. Therefore we may consider it as certain that the largest part of free CO_2 in the

ocean is held as the second equivalent of bicarbonate, and that this is held in equilibrium with the gas in the air.

We know then from the above that the dissociation of the bicarbonate is a function of the temperature, and also of the partial pressure of the superincumbent CO_2. The solubility of CO_2 as a gas not attached to form bicarbonate, is also a function of temperature and pressure, but that these functions are not the same, may be seen from an inspection of the

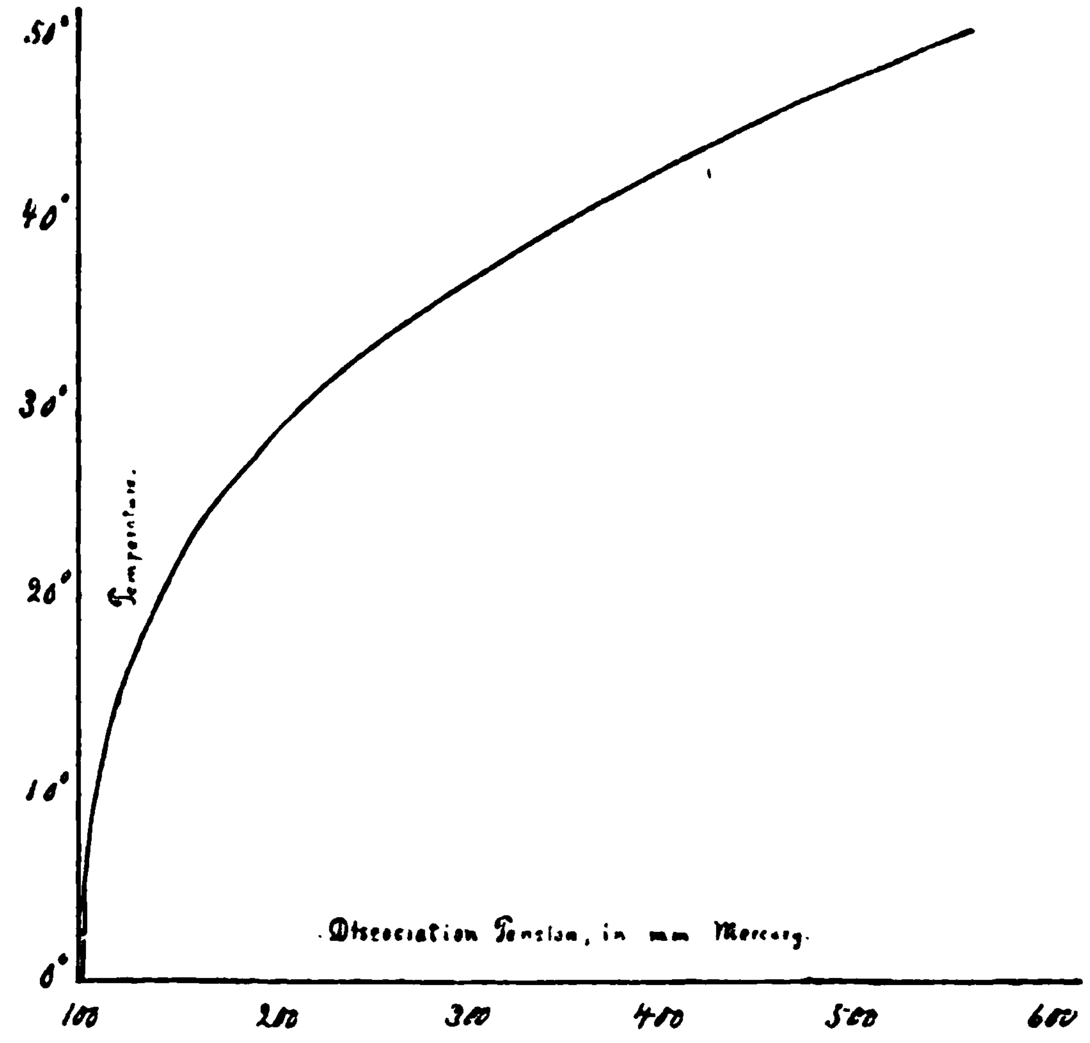


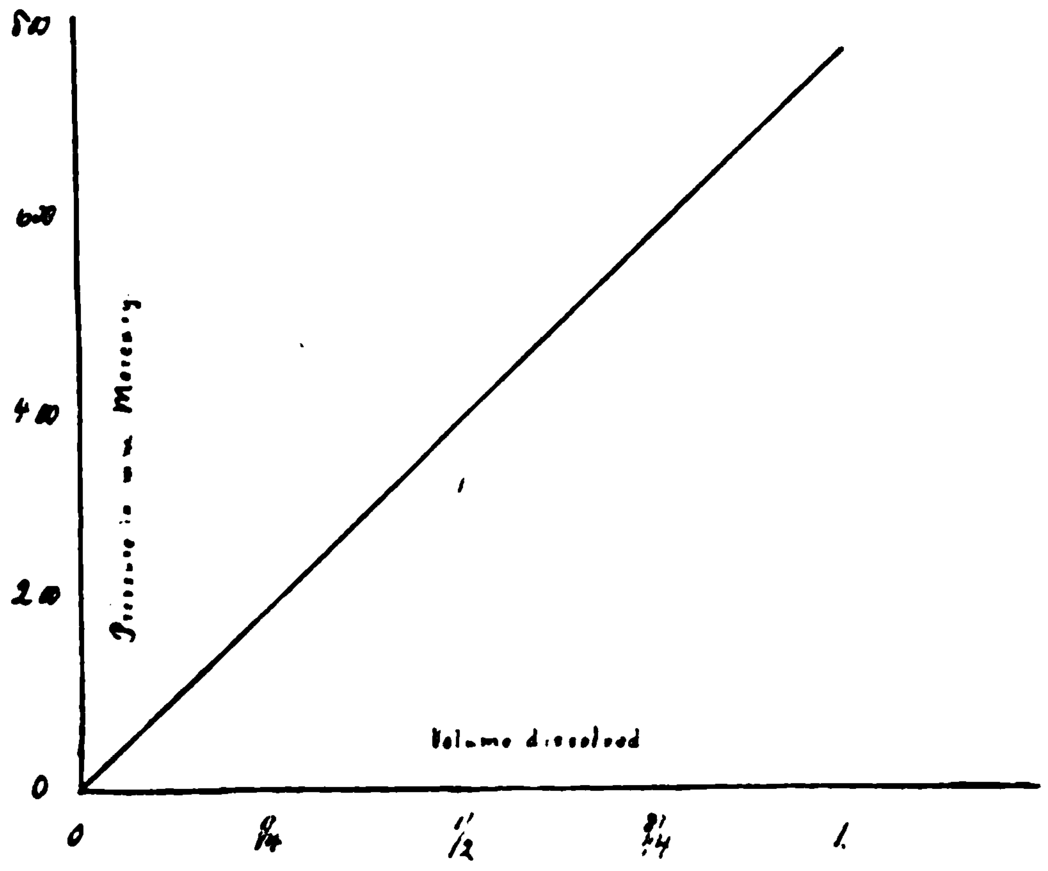
FIG. 2 is plotted from Dr. Dibbett's tables.[1] On the ordinate are the temperatures and on the abscissa the increase of the dissociation of the Na H CO_2 in mm of mercury which represents the loss of the second equivalent of CO_2 from the solution.

accompanying curves. Professor Ditmar has experimented upon the effect of changes of partial pressure and temperature upon the CO_2 in the ocean. This includes both the effect upon the portion simply dissolved and that as second equivalent of bicarbonate. We shall discuss these results under Professor Arrhenius' hypothesis of lowering the surface temperature to

[1] Ueber die Loslichkeit und die Dissociation des sauren kohlens Kaliumes, Natriurns und Ammomiums, Journal für praktische Chemie, neue Folge 10, 1879, pp. 417-444.

an average of 10° C., and the diminution of the partial pressure he has postulated as sufficient to cause this drop in temperature.

We find from Professor Ditmar's investigation (see tables and figures, pp. 609 and 610) that as the waters of the ocean become warmer, the effect of a change in the partial pressure of atmospheric CO_2 upon the bicarbonate dissociation becomes greater, while near zero a change in partial pressure has no effect on the dissociation of the bicarbonates of the ocean. On the



FIGS. 3 and 4 show the relation between the partial pressure of CO_2 and its solubility in pure water on the one hand and the solubility of Ca H_2 $(CO_3)_2$ on the other.

FIG. 3 represents the simple law of gas absorption that the amount dissolved is directly proportional to the partial pressure. The pressure is plotted on the ordinates in mm of mercury and the volume of gas absorbed on the abscissa.

other hand, the effect of any postulated fall in temperature, causing the bicarbonates to take up CO_2, is the greatest at the temperature just above 0°, and becomes less for higher temperatures. So that a fall in temperature of the colder waters of the ocean is correlated with the greatest absorption of CO_2, and without the counteracting effect of decreasing partial pressure. In equatorial waters, however, the fall in temperature does not

produce so great an increase in the absorption of the CO_2, and the effect of decreasing tension of atmospheric CO_2 approaches a maximum.

These facts, therefore, naturally divide the discussion into three parts. Under Professor Arrhenius' postulates as to change in temperature and pressure, we shall discuss the relative effect of these two opposing factors in the temperate waters whose temperature is the average surface temperature of the ocean, viz., 15° C. (2) Ditto for the tropical waters whose temperature is above 15° C. (3) Ditto for the polar waters whose temperature is below this.

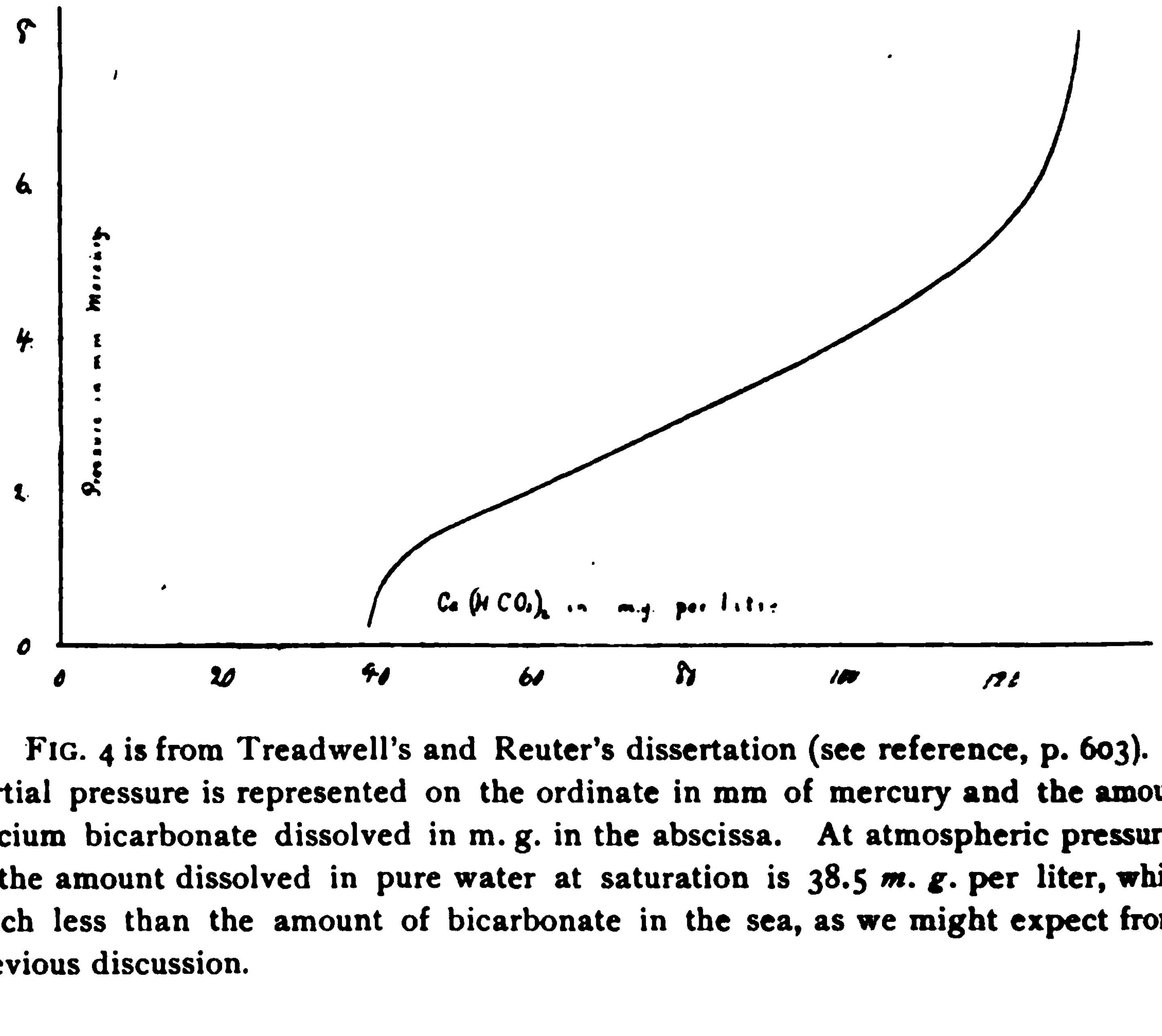


FIG. 4 is from Treadwell's and Reuter's dissertation (see reference, p. 603). The partial pressure is represented on the ordinate in mm of mercury and the amount of calcium bicarbonate dissolved in m. g. in the abscissa. At atmospheric pressure 15° C. the amount dissolved in pure water at saturation is 38.5 *m. g.* per liter, which is much less than the amount of bicarbonate in the sea, as we might expect from the previous discussion.

The only experiments which have been made upon sea water (and so under the actual conditions of the problem) are represented in Fig. 5. Professor Ditmar took a special sample of deep ocean water which was so charged with CO_2 as to have its bicarbonate fully saturated with CO_2. This he shook violently in a bottle constantly renewing the air until there was no more

loss of CO_2 from the water and no more gain in the air above the water. The carbon dioxide remaining in the water was thus determined, and the degree of the bicarbonate dissociation calculated. This was repeated for various temperatures.

The table is as follows :[1]

t	N	Pure Air (n_0)	Ordinary Air (n_1)
2	200	1.90	
2	200	2.04	
2	52		2.06
10	200	1.70	
13	50		1.84
15	100	1.63	
15	200	1.50	
20	200	1.42	
25	53	1.53	
32	52	1.33	
32	52		1.89
32	150		1.8z

t=equals temperature. N=number of times air was renewed until loss of CO_2 from water ceased. n_0=ratio of first to the second equivalent of CO_2 in bicarbonate when shaken in air free from CO_2, where 2.00 represents fully saturated bicarbonate and 1.00 simply the normal carbonate. n_1=the same for ordinary air.

These experimental data do not permit the drawing of any very accurate conclusions. Professor Ditmar states that these are only preliminary, and has promised us a completion of this work, which we await with impatience. However, we must needs use what we have, and referring to curve 5, we see that at 15° the ocean will contain about 83 per cent. of the total second equivalent of CO_2, and at 10°, about 88 per cent. of it, or an increase of 5 per cent. of the second equivalent which is represented by the line *a–b* in figure. For pure air artificially freed of CO_2 at 10° the dissociation goes through 70 per cent. but Professor Arrhenius does not postulate a complete removal

[1] Enyc. Brit., Vol. XXI, p. 612.

of CO_2 from the air, but a diminution of from 62 per cent. to 55 per cent. of the present partial pressure of the gas, and this decrease in dissociation caused by the decrease of the partial

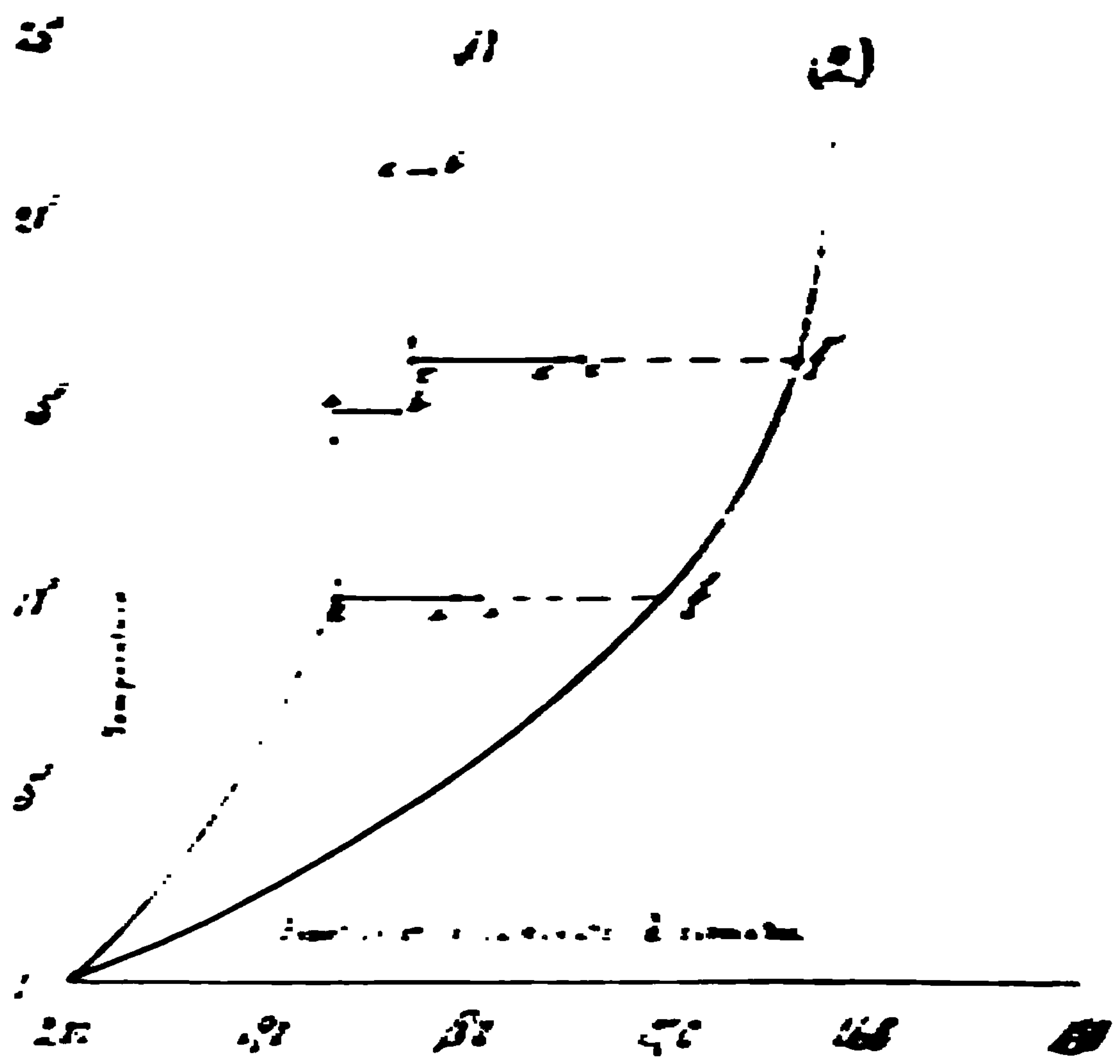


FIG. 5 is plotted from Professor Dittmar's table on page 609. The figures in the table are not very constant, but we have taken those that seem to correspond best with each other. On the ordinate are the temperatures, and on the abscissa the dissociation of the ocean bicarbonate, 100 representing fully saturated bicarbonate and 100 normal carbonate, the partial pressure of CO_2 in the curve (1) is that of the atmosphere as it is at the present time and for curve (2) there is 0 pressure of that gas. The two curves have been plotted arbitrarily to cut a 0°, but Professor Dittmar shows that there is probably no dissociation at 2° to 3° above zero.

The line *gf* connects the two curves at 10° (the temperature of the temperate regions Dr. Arrhenius postulates to develop a glacial period), and the points *d* and *e* show the bicarbonate dissociation at a partial pressure of CO_2 reduced respectively to 62 and 55 per cent. of its present value. *a b* represents the decrease of the dissociation of the bicarbonates due to fall of temperature from 15° to 10°; and *c d* and *c e* the increase of the dissociation due to a decrease of 62 per cent. and of 55 per cent. of the present value of the partial pressure of CO_2 in the air. *a b* and *c d* and *c e* represent the same factors for a decrease of temperature from 21° to 10° and the same decrease as postulated above in the partial pressure of the CO_2.

pressure of the gas is represented by lines *c–d* and *c–e*; so that the dissociation will be between the two, that is, viz., from 76 per cent. to 81 per cent., *i. e.*, these data show that the falling

temperature counteracts within 2 per cent. to 4 per cent. of the total CO_2 as second equivalent, the effect of the decrease in the partial pressure.

These estimates are of course founded on too small an experimental basis, and the data themselves show too great disagreements to conclude that the decrease of the dissociation due to the falling temperature, counteracts exactly within 2 per cent. to 4 per cent. of the second equivalent of CO_2, the increase due to the diminishing partial pressure ; but we may conclude *that they are probably of the same order of magnitude*, or that *a–b* is comparable in length with *c–d* or *c–e*.

All this however, is under the proposition of Professor Arrhenius, that a 5° lowering of the average climate of the *temperate* regions will bring on glaciation. We have still to consider the effect of the waters of the equatorial region on the one hand, and those of the higher latitudes on the other.

The average temperatures of the ocean waters at the surf line between 45° north and south latitudes, are as follows :[1]

For the belt between 15° north latitude, and 15° south latitude, 26 degrees centigrade.

For the belts between 15°–30° north latitude, and 15°–30° south latitude, 21 degrees centigrade.

For the belts between 30°–45° north latitude, and 30°–45° south latitude, 17 degrees centigrade.

The average temperature between 45° north latitude and 45° south latitude, at the depth of 1500 fathoms is between 2°–3° centigrade.

Professor Ditmar has found that at temperatures between 18°–21° C. that the dissociation tension of the bicarbonates of the sea water is five ten-thousandths of an atmosphere. On the other hand, at temperatures near zero, the dissociation does not take place, and the tension of course becomes nil. (See table above.)

The partial pressure of the CO_2 in the atmosphere at the present time is about three ten-thousandths. Therefore, he con-

[1]Compiled from tables Challenger's Rep., Vol. I, Table VI, at end of volume.

cludes that the warmer portions of the ocean are constantly supplying CO_2 to the atmosphere, and the colder portions are always removing it.[1]

The falling temperature which causes the glacial period must affect the temperature of the surface of the equatorial water, especially after an ice advance is inaugurated, but how much we cannot estimate. Taking the average surface temperature of these waters as 21°, and postulating the same fall of temperature as for the temperate waters, we see that the line $a'\ b'$ repsenting the decreasing dissociation due to the falling temperature, is much shorter than the line $c'\ d'$ or $c'\ e'$, representing the increase in the dissociation caused by the decreasing partial pressure of CO_2. However, the data upon which this part of the curve is based are much more conflicting and less satisfactory than those represented by the curve at 10°. But we may conclude that in the equatorial region the diminishing partial pressure has a greater effect than the postulated fall of temperature. But, with the increasing cold, the heated areas which can give off carbonic acid to the air are greatly diminished, especially after the glaciation has commenced, and this acts directly counter to the diminishing partial pressure.

In the northern seas whose surface temperature is near zero, each molecule of carbonate has the power to take up carbonic acid until it becomes a fully saturated bicarbonate. Just how much increase this area will undergo on an approach of a glacial period we cannot well estimate, but perhaps we can get a fair idea of it by comparing the area of the ocean contained within the circle of latitude which bounds the northernmost point of Greenland glaciation with that contained within the circle bounding the southern limit of Pleistocene glaciation. The ratio between these two areas is 2 : 5. These figures may not even approximately represent the real increase of the cold waters during glacial times, but they emphasize the fact of an actual and great increase in the amount of these waters.

The table on p. 609, as stated before, shows that at low tem-

[1] Chal. Rep., Vol. I, pp. 212, 213.

peratures the decrease in the partial pressure of the atmospheric CO_2 has practically no dissociating effect upon the bicarbonates of the ocean, and therefore that the large increase in the capacity for absorbing CO_2 is not affected by the diminishing partial pressure.

To sum up then: (1) the increase in the ocean's capacity for CO_2 at low temperatures, and (2) the invasions of the polar waters toward the equator, both tend directly to rob the atmosphere of CO_2, unaffected by any diminishing partial pressure of that gas. In the temperate waters the effects of increasing cold and decreasing partial pressure seem to be fairly evenly balanced, with a possible advantage for the diminishing partial pressure, against which must be reckoned a decrease in the amount of these waters. In the equatorial waters the effect of the decreasing partial pressure exceeds that of falling temperature, counterbalanced by a large decrease in the amount of these waters.

This division of the ocean with three belts shows us clearly the factors in the problem, but does not give us means by which to find the relative values of these factors—that is, to show us whether or not the intensifying factors, such as falling temperature and increasing areas of polar waters and decreasing areas of equatorial waters, more than counteract the effect of the diminishing partial pressure of the CO_2 over the temperate and equatorial waters.

In order to get some rough comparative value of these factors without pretending to get any accurate quantitative estimate of their actual value, we have tried to estimate the volume of the ocean water, whose temperature is reduced from 7° to 2°, from 12° to 7° and from temperatures above 12°, etc., and to calculate the amount of CO_2 these volumes of the waters can absorb on account of their lower temperature on the one hand and to estimate the greatest amount of CO_2 that might be freed from the tropical waters compatible with their restricted volumes on the other hand.

As shown in Fig. 6, we have assumed that the polar waters

(viz. those with temperature of 2°–3° C.) will advance southward at least as far as the southernmost limit of the ice-sheet. Therefore, we have started the line *a b* at 60° N. and S. latitude (the latitude of the southern Greenland glaciation) and the line *e h* at 37° (the latitude of the southernmost Pleistocene glaciation in North America). With this postulated southern advance of the cold waters, there must also have been a rise of these cold waters toward the surface. The amount of this rise is undeterminable at present. But since we have used Dr. Arrhenius' estimate of a drop of 5° in the temperature of the surface waters, we may assume the same fall of temperature for the body of the ocean. A given fall in temperature of the surface water must

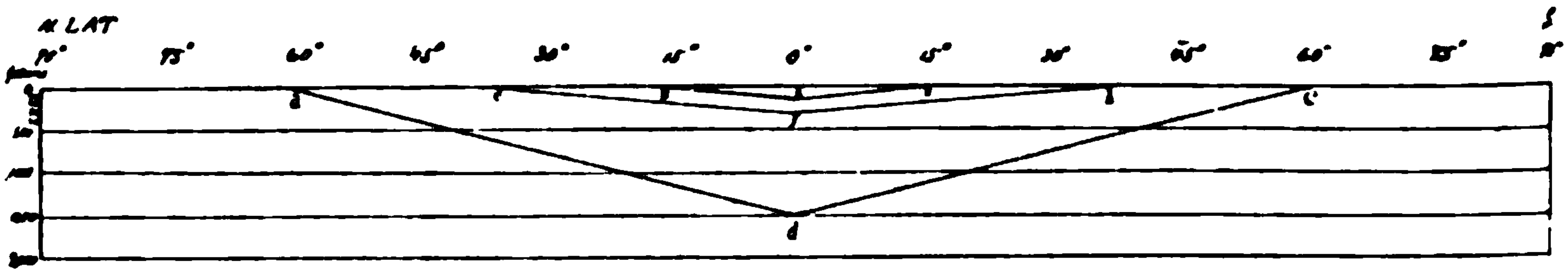


FIG. 6.—Section of ocean from north to south pole. Ocean taken at average depth of 2000 fathoms. Portion below 1500 fathoms has temperature below 2° to 3° C.

Line *a d c* incloses section of ocean whose temperature is now above 2° to 3°. Line *e f h* limits the equatorial and upward migration of the polar waters during maximum Pleistocene glaciation, when the ice reached the latitude 37° N.

Line *m k n* ditto for waters with Pleistocene temperature of 2° to 7°.

Above line *m k n* ditto for water of higher temperature.

take a very long time to communicate itself throughout the body of the ocean, but the larger the period during which the surface waters maintain their low temperature the more completely does the body of the ocean lose its extra heat.

At 1500 fathoms the temperature of the temperate and equatorial waters is 2°–3° C. above zero; therefore, the maximum depth which the line *a–c* reaches is placed at *d*. At 300 fathoms the warm waters have a temperature of about 7°.[1] Therefore, we place here *f* on the line *e f h*, designating the maximum advance upwards of the polar waters.

Point *k* on *m-k-n* is 150 fathoms below the surface and at that

[1] All temperatures calculated from tables of temperatures, given in Vol. I of the Challenger Reports.

depth the equatorial waters have average temperature of 12°. Therefore, this will be the limit of the waters of the belt that had temperatures of 2° to 7° during maximum glaciation. Above *K* are the waters which now have temperatures above 12°, and during glaciation temperatures above 7°.

To get a correct conception of this section of the ocean waters from pole to pole, we must multiply the length given here by 550.

The portion of the ocean below 1500 fathoms is already down to the limiting temperature; therefore, its carbon dioxide content is not subject to fluctuations. This leaves out of the 18 atmospheres of "free" CO_2 about 13 atmospheres above the 1500 fathom line.

The volume of these waters is divided as follows:

90° to 60° N. and S. latitudes, - - -	11%
60° to 37° " " - - -	24
37° to 6° " " - - -	65

Now, the volume of water included between *a d c* and *e f h* is considerably over one half that above the 1500-fathom line, or it holds about seven atmospheres CO_2, and a change of temperature from 7° to 2° represents a change in the dissociation of the bicarbonates from 1.9 to 2.00 (see Fig. 5, p. 610), or more than a 10 per cent. increase in the "free" CO_2. Therefore, this advance of the cold waters upward and toward the equator represents an increased capacity of the ocean for CO_2, equal to about seven tenths that of the present atmosphere.

The waters above *m k n* represent those which now have a temperature above 12° C. (we neglect the warm surface waters now spread far poleward by the warm currents), and it is in the warmer of these waters that the diminishing partial pressure of the CO_2 may cause a loss of CO_2 from the ocean.

Now this volume represented by *m k n* is considerably less than 2 per cent. of the volume above the 1500 fathoms line, so that for a limiting case if *all* the second equivalent were lost in these waters, instead of only at most a small portion of it, it would amount to less than one third that gained by the advance of the

cold waters, and in the actual case probably not more than one-fourth of the same.

Admitting all the inaccuracies of our assumptions, still it seems to be clear that with falling temperature *the ocean will absorb CO_2 from the air.*

The effect becomes more pronounced as the glaciers become more extensive and thus directly chill the ocean waters. We offer this as the most important accumulative factor causing the great extent of the glacial invasion, acting until overcome by a number of opposite agencies.

Dr. Chamberlin[1] has shown that the amount of CO_2 in the atmosphere at any one time, and therefore the climate of the earth at that time, depends upon the value of the ratio of the supply of the gas to its depletion. Besides the continuous supply that the atmosphere receives from the interior of the earth and from planetary space and the continuous depletion due to the formation of the carbonates in place of the igneous alkali earth silicates, there are variations in the ratio of supply to depletion dependent upon the attitude of the land and water.

A large exposure of land surface is correlated with a rapid solution of calcium and magnesium carbonates, and this solution is accompanied by a change from the normal carbonate to the bicarbonate form, and therefore represents a loss of CO_2 from the atmosphere.

On the other hand the formation of the normal carbonate by lime-secreting animals causes a direct liberation of the second equivalent of the bicarbonate. Therefore extensive oceans and abundant marine life are correlated with warm climate, and restricted seas and elevated land cause loss of CO_2 and colder climate.

Now to investigate the rôle the ocean plays in this conflict:

1. The chief agencies in the *removal* of the carbon dioxide from the air are (a) the formation of the carbonates from the silicates, (b) the solution of the carbonates as bicarbonates. These are dependent upon the attitude of the land and water.

[1] See Papers of T. C. Chamberlin, Jour. Geol., Vol. V, p. 682.

the elevated land being accompanied by rapid disintegration and erosion. The increasing cold only slightly affects this process (a′) by the decrease in vegetation; (b′) by the slight decrease in chemical activity of the CO_2; (c′) by the freezing of the ground, preventing free percolation of the underground water, etc. But it aids disintegration by frost action, etc. (c) The polar seas constantly absorb CO_2 from the atmosphere. The increasing cold, with the increasing volume of cold waters, therefore *directly robs* the atmosphere of the CO_2. This process is not so marked in the warmer waters, because of the counteracting effect of the postulated diminishing partial pressure of CO_2.

2. The *supply of* CO_2, outside of that of plutonic and extra-terrestrial origin comes (a) from the dissociation of bicarbonates in equatorial waters. The decreasing partial pressure aids this and the restricted area of warm water counteracts it. (b) The second equivalent of bicarbonate freed by lime-producing animals. The fall of temperature directly affects this most important source of supply, as it is well known that a fall of a few degrees in the ocean water would wipe out whole genera of test-producing animals.

To sum up, then: Accepting Dr. Chamberlin's proposition that the advance of a cold period is primarily dependent upon the altitude of land and water, the effect of the ocean is both to remove the atmospheric carbonic acid gas by the southern and upward invasion of the cold waters, and to decrease the supply of CO_2 to the atmosphere by the destruction of the lime-secreting animals. Therefore we conclude that *the ocean very greatly intensifies the secular variation of the earth's temperature, although acting as a moderating agent in the minor cycles.*

It is interesting to note what a different state of affairs we would have if the CO_2 in the ocean were simply dissolved as a gas from the atmosphere according to the laws of gas absorption. A diminution of the partial pressure of the CO_2 in the atmosphere, as postulated, would bring out of the ocean 38 to 45 per cent. of its great store of CO_2. A lowering of 5° in

temperature from 5° to 0° would only produce an increase in the solubility of the gas of 24 per cent., and from 20° to 15° of [illegible] per cent., and so, under such conditions, an excess of [illegible] to [illegible] per cent. of all the CO_2 in the ocean would have to be removed and consumed before a cold period could be inaugurated.

Although future investigations may cause a modification in Dr. Arrhenius' estimate, and such a change will affect some of these conclusions, the principles on which they are based will not be affected. If it be found that on account of certain intensifying agencies, or for other reasons, it is not necessary to postulate so large a decrease of the CO_2 of the atmosphere, or if this decrease is accompanied with a greater fall of temperature than 5°, then the depleting effect of the ocean will become more marked. If, however, the estimated decrease of the atmospheric CO_2 is too small, the intensive effects may be lessened, but probably not completely destroyed.

CYRUS F. TOLMAN, JR.

EDITORIAL

It is gratifying to know that the excellent work of the Missouri Geological Survey is to be continued and that it is even proposed "to eliminate all ornamental or irrelevant fancies and go directly after the fundamental facts which make the only logical foundation for a geological survey." It is true that among the "ornamental" facts to be eliminated are such things as "Engineering Instruments, Photographic Apparatus, Laboratory Equipments" and a few others which ordinary geologists have come to consider indispensable. However, it is no ordinary man or ordinary plan of work that Missouri now has on its hands. In a recent St. Louis interview the state geologist announces that "The rocks have never been differentiated in Missouri and Arkansas"—thus setting aside at one stroke of the pen all the results of former work in the region. Fortunately such a dire condition is not to be allowed to continue, and the new state geologist proposes to issue at once a preliminary report in which "I will differentiate the rocks to a finish." He also proposes to give "photographic views of two or three of the best exposures of each rock in the state," from which we may infer that since his *Biennial Report* was issued he has fallen into evil ways and has begun to lean a little on the "ornamental" and "irrelevant" aids of other members of his profession. This new work is to be very thorough and the sedimentary rocks are to be taken, "one at a time, from Z to A."

Incidentally he will courteously give in the report a synopsis of a new "cosmic philosophy" which he has worked out "with only physics, logic and consciousness as guides." With such noble companionship it is no wonder that ordinary grammar is considered out of place. At least we may judge this to be true from such statements as, "Several dykes of diabase were crossed

in the county, as well as rumors of rich deposits, etc."[1] This sentence gives one some new light on classification and will perhaps obtain for the doubter pardon for his skepticism whether the new differentiation is to be so very thorough after all. When diabase dikes and rumors are classed together, there seems room for doubt as to the closeness of the classification. However, all things are possible to one who can explain dolomite as formed in Sargasso seas and can settle the glacial problem in one short page. The proposed preliminary report will be eagerly awaited ; the *Biennial* is all too brief a pleasure.

H. F. B.

[1] Biennial Report of State Geologist, 1898, p. 36.

REVIEWS.

The great Ice-dams of Lakes Maumee, Whittlesey and Warren. By FRANK BURSLEY TAYLOR, Fort Wayne, Ind. American Geologist, July 1899, Vol. XXIV, pp. 6–38, Pl. II and III.

Two years ago Mr. Taylor contributed to Pleistocene geology a new working hypothesis.[1] Pointing out that the recessional moraines left by certain lobes of the Laurentide ice sheet on plains or in broad smooth valleys were characterized by regularity of interval, he postulated that this regularity was caused by a definitive rhythm in the general conditions controlling the magnitude of the ice-field; whatever may have been the cause of the general wasting of the ice, its action was modified by a concurrent cause of a rhythmic nature, which alternately promoted and opposed the wasting. Under the joint action of the two causes the ice front first retreated with comparative rapidity, then halted, readvanced slowly over part of the abandoned territory, and finally halted a second time before beginning a second cycle; and each recessional moraine marks the position of the ice front at the close of such a cycle. This hypothesis, if well founded, is of far reaching importance. It affords a basis for the correlation of moraines in widely separated districts, and for the mapping of the ice sheet at various stages of its final waning. It affords a regularly graduated chronologic scheme of classification. It leads to an estimate of the duration of a definite portion of geologic time, far superior to any based on phenomena of erosion. And it probably assists in the discussion of the cause of the ice age.

When the hypothesis was first presented it was applied to the making of a time estimate. In the present paper it is applied to local geology, the correlation of moraines and associated phenomena in a district about Lakes Erie and Huron. After a general discussion of the function of the ice front as a dam to retain glacial lakes, and of the theoretic relations of successive positions of the dam to cols, and the

[1] Moraines of Recession and their Significance in Glacial Theory. JOUR. GEOL. Vol. V, 1897, pp. 421–465.

resulting location of shore lines and channels of outlet, an account is given of the actual positions of the ice-dam within the district and of the resulting series of glacial lakes. A map of moraines includes not only data from various sources previously publisht, but important new material, especially for the Canadian peninsula, and is adjusted to the subject in hand by the indication of the theoretic continuations and connections of partly surveyed moraines. Other maps show the glacial lakes, outlined with detail and confidence not only on the land side, where their shores are still preserved as dry beaches and terraces, but also the ice side, where all actual vestige has necessarily disappeared.

Lake Maumee, in the western part of the Erie basin, lasted during three oscillations of the ice front, growing larger with each shifting of the dam. At first its discharge was at Fort Wayne and thence down the Wabash River; afterwards part of its surplus escaped across the "thumb" of Michigan at Imlay, running westward to the Lake Michigan basin. In the later part of its life the broad upland of the peninsula of Canada was a nunatak. Lake Whittlesey, succeeding Lake Maumee in the same basin, held place for a single morainic cycle. The Canadian upland, no longer a nunatak, formed part of its northeastern shore, separating two ice lobes. Its discharge crost the thumb of Michigan at Ubly to a lower glacial lake, Saginaw, and thence ran westward through the Pewamo channel across the lower peninsula of Michigan. Lake Warren, uniting Lakes Whittlesey and Saginaw, at the level of the latter, endured for four morainic cycles, being greatly modified in outline by the successive changes of the retaining dam and becoming eventually much larger than its predecessors.

It is to be noted that the author did not delay the publication of his generalization until the ground had been wholly covered by observation nor until all the observations made use of had been verified. While guarding against misapprehension by constantly drawing the line between fact and theory, he has freely used his working hypothesis for purposes of local interpolation. To whatever extent his local generalizations are deductions from theory they will eventually, through the extension of observation be made to serve as tests of the theory.

Taylor dwells on the peculiar significance of the Ubly channel as an evidence of the existence of glacial lakes and a glacial dam, and closes with a general argument (drawn out by criticisms of J. W. Spencer) in support of the fundamental theory that the ice sheet served as a dam for the retention of lakes.

A corollary of some interest, not mentioned by the author, relates the history recorded by recessional moraines to that associated with Niagara gorge. From the beginning of the last ice retreat at Cincinnati Taylor counts seventeen moraines to Rochester, beyond which point new conditions enter, making the continuance of the analysis a matter of great difficulty. But just at the close of the term represented by these moraines the Niagara began its work, so that the moraine history is complemented by the river history. Together they represent all the time since the latest ice maximum, a period whose measurement in years is far more valuable to science than the determination of the age of the great cataract. Postulating the astronomic cycle of the precession of the equinoxes as the cause of the morainic cycle, the approximate time covered by the morainic history is computed (by the reviewer) at 315,000 years. This is so long a period in comparison with the most ample of modern estimates for the age of the Niagara that the uncertainty as to Niagara's age is of little moment in considering the sum of the two periods. Broadly stated, the hypothesis that the recessional moraines are functions of the precessional cycle estimates the time since the last maximum of glaciation at 300,000 to 400,000 years.

G. K. G.

The Influence of the Carbonic Acid in the Air upon the Temperature of the Ground. By PROFESSOR SVANTE ARRHENIUS. *Philosophical Magazine and Journal of Science*, Vol. XLI (Fifth Series) 1896, pp. 237–276. *La Revue Générale des Sciences*, Mai, 1899, pp. 1–22.

Professor Arrhenius was led to investigate this subject by the debates among the Swedish geologists upon the cause of the glacial and interglacial climates of the Pleistocene. The conclusion that none of the current hypotheses are satisfactory or at all competent to explain the observed phenomena led him to calculate the quantitative effect of any given variation in the amount of atmospheric carbon dioxide upon the temperature of the earth's surface. The fact that the carbon dioxide and water vapor are the chief agents in retaining the heat radiated from the earth's surface had long been known qualitatively and even the relative values of the selective absorption of radiant energy for the various atmospheric gases had been determined, but it remained for

Professor Arrhenius to show the exact effect of any given change in the carbon dioxide content of the atmosphere upon the surface temperature of the earth.

The essential work of the physicist and mathematician having now been done by him, it remains for the geologist to investigate the various sources of supply and depletion of carbon dioxide and to determine if possible if there have been any variations of such an order of magnitude as to produce the results observed.

Professor Arrhenius explains in his papers that the air retains heat (light and dark) in two different ways: (1) The heat suffers a selective diffusion as it passes through the air. This is greatest for the rays having short wave-lengths (ultra-violet) and insensible for those of long wave-lengths which form the chief part of the radiation of a body of the temperature of the earth, viz., 15° C. (2) The gases themselves have the power of absorbing selectively the light and heat of certain wave-lengths. The carbon dioxide and the water vapor have this power of selective absorption to a far greater extent than the oxygen, nitrogen or argon, and this absorption is not distributed evenly throughout the spectrum but occurs in certain definite bands which are best developed in the ultra-red portion which represents the rays with long wave-lengths such as are given off by bodies with a low temperature.

There are two ways in which to measure the amount of the heat absorption by the carbon dioxide and the water vapor: (1) by measuring directly the amount of heat absorbed by such quantities of these gases as they appear in the atmosphere, and at a temperature of 15° C., and (2) by measuring the amounts of heat received from the full moon at different heights above the horizon. The amount of carbon dioxide through which the rays pass is evidently a function of altitude of the moon above the horizon, while that of the water vapor depends both upon the altitude and the humidity of the air.

Professor Arrhenius takes the second method and from Professor Langley's observations on the heat received from the full moon at various altitudes above the horizon he calculates the amount of heat absorbed by the two gases by an atmosphere having the present average amount of carbon dioxide and the average amount of water vapor, viz., ten grains per cubic meter at the earth's surface. The full moon has, however, a surface temperature of 100°, and he introduces the corrections necessary to apply the above to a body with the temperature of 15° C.

With these data it is not difficult to calculate the effect of any change in the amount of carbon dioxide upon the temperature of the surface of the earth. The temperature of the earth's surface is theoretically in equilibrium with that of the atmosphere. Now if by any increase in the amount of the carbon dioxide the atmosphere retains more heat than before, it will radiate more heat to the surface of the earth. The surface temperature then will rise until there is again an equilibrium between the two. This rise is governed by Stefan's law which states that the intensity of the radiation is proportionate to the fourth power of the er

From these data Professor Arrhenius finds that if the carbon dioxide is increased 2.5 to 3 times its present value, the temperature in the arctic regions must rise 8° to 9° C. and produce a climate as mild as that of the Eocene period. A diminution to 0.62 to 0.55 of its present value must cause a fall of from 4° to 5° C. and give us a glacial period.

It is to be noted that in every case throughout the calculation Professor Arrhenius has preferred to slightly underestimate the effect of the carbon dioxide than to risk a possible overestimate. Also where he has been compelled to use interpolation the limit of error has been well within the degree of accuracy of the observations upon which they are founded.

The tremendous interest of these considerations, not only as a basis for the interpretation of the past history of the globe but also for the prophecy of its future, demands an investigation of the problem along the lines of direct experiment, as a supplement to the elegant calculations of Professor Arrhenius.

CYRUS F. TOLMAN, JR.

Special Report on Gypsum and Gypsum Cement Plasters. By G. P. GRIMSLEY and E. H. S. BAILEY. University Geological Survey of Kansas, Vol. V. Pp. 183, 30 plates. Topeka, 1899.

Among the minor mineral industries of the country those connected with gypsum have been, so far as literature is concerned, heretofore neglected. The present report is accordingly particularly welcome. The papers so far accessible have been, in the main, devoted to the description of local deposits and the technology of the gypsum industries has not been described before in any adequate manner. The present volume includes not only a description of the Kansas gypsum beds

[illegible] gypsum of other states and countries and a [illegible] processes. The body of the work is by Dr. Grimsley while Professor Bailey contributes a valuable chapter dealing with the chemistry of the subject.

In 190[illegible] Kansas produced [illegible] tons of gypsum which had a value of $[illegible]. It was a little behind Iowa in production and ahead in value, the difference being in the large proportion of the Iowa product sold as land plaster. Aside from these two states Michigan and New York are the main producers. The Kansas gypsum is found in three fields: the Northern or Blue Rapids area mainly in Washington and Marshall counties, the central or Gypsum City area in Saline, Dickinson and Marion counties, and the southern or Medicine Lodge area in Comanche and Barber [illegible] counties. The beds occur in the Permian of Prosser's classification and the deposits include the original rock deposits and the derived gypsum earths which are of recent origin. These gypsum earths are the distinctive beds of the Kansas-Oklahoma district and are thought to be marsh deposits deriving their peculiarities from the secondary deposition of gypsum in clays. They are used in the production of gypsum cements and are mined by ordinary surface methods. The rock gypsum is won by underground mining on a room and pillar system, [illegible] would have been valuable, and is used in the production of plaster of Paris and other products.

The Kansas milling practice does not seem to differ from that of other districts especially, though the Stedman disintegrator has been introduced and a [illegible] air blast is used at one point to elevate the calcined plaster. Here as elsewhere grinding is in the main done by stones and it seems peculiar in view of the great progress of recent years in fine grinding machinery that the numerous experiments in the direction of cheaper and more expeditious grinding have never borne fruit in the gypsum industries. Burning is done in the ordinary Mason [illegible] kettle. It would seem that in the case of the gypsum earths at least the rotary furnaces now so much used could be applied to advantage.

In the discussion of the set of the plaster Dr. Grimsley has contributed some highly interesting and valuable microscopic studies in which he shows in brief that the strength of the set plaster depends upon the formation of a network or felt of fine lath-shaped crystals and that the [illegible] agents in this setting process are the few small

crystals present in the dry plaster. This accords well with all the known facts in the case and is furthermore in line with Jameson's observations on the setting of Portland cements. It explains some of the peculiarities of the behavior of retarders though in the matter of that vexed subject but little that is new is brought out. If the subject of the strength, and rapidity of set of the gypsum cements could have been gone into a little and illustrated by tensile strength and other tests it would have added greatly to the value of the book and have aided in defining the sort of situations in which these cements could be used to best advantage. In the form of hard white finish they now dominate the market so far as interior work is concerned but the advisability of using them for wall work in any general way is open as yet to some question. This is particularly true in view of the strength and cheapness of magnesian limes and the availability of non-sulphate cements.

Dr. Grimsley's report is a valuable one, particularly in its technical as distinguished from its geological phases. It will undoubtedly have a large influence on the gypsum industry of the state and is a credit to the vigorous Kansas Survey. H. F. BAIN.

American Cements. By URIAH CUMMINGS. Pp. 299, 8 vo. Rogers & Manson, Boston. 1898.

In the rapid introduction of Portland cements in this country the importance and value of the Roman cements bid fair to be overlooked. At present there is what the author fittingly nominates a "craze" for quick setting, high testing cements, and the slower setting, cheaper grades are looked upon in many quarters as of very little value. Mr. Cummings' long experience in the manufacture of cement and his wide interest in the subject admirably fit him to discuss it. In this little book he has gathered together much scattered information and has added very much from his own experience. His interpretations of the chemical processes involved in the making and the setting of cements will. doubtless arouse much opposition; particularly in his plea for the magnesian cements, but where so much is uncertain any hypothesis backed with such facts as Mr. Cummings marshals must necessarily receive careful attention. Taken as a whole the book is one of which no one interested in cements and the utilization of our limestones and shales, can afford to remain in ignorance.

H. F. BAIN.

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THE PLIOCENE SKULL OF CALIFORNIA AND THE FLINT IMPLEMENTS OF TABLE MOUNTAIN

THE celebrated skull from Calaveras county, California, claimed to have been found at a depth of 130 feet in the auriferous gravel deposits of a Pliocene river "beneath the lava, in the cement, and in close proximity to a completely petrified oak" was exhibited by Professor J. D. Whitney at the Chicago meeting of the American Association for the Advancement of Science in the month of August 1868.

At that time the attention of the Association in general session was directed by the writer to certain conditions and peculiarities of the relic which made it unreasonable to accept it as coming from the deep gravels of a river. The objections then made to the skull as evidence of man's great antiquity do not appear to have been reported or recorded, having been given in the course of the discussion and not in a paper of record.

One chief reason for the rejection of the skull as coming from the gravelly bed of an ancient river is the entire absence on its surface, or on its broken edges, of any marks of attrition. If the skull had ever been rolled along the bed of a river with the bowlders and gravel, it would bear the marks of the violent pounding and wearing action to which any bone or object occurring in such gravels is subjected. In fact, a hollow bone or least

of all a human skull, could not remain intact, or even so well preserved a fragment as the skull in question, under such violent and abrasive conditions—conditions resulting in the rounding of the edges of pebbles and bowlders and in flattening out pellets of gold.

Those familiar with the auriferous gravel deposits, even of slight depth in modern rivers, know how the smaller materials fill every interstice of the bedrock, and, in the case of the bones of the mammoth and of the mastodon, how the foramens of the teeth and any cavity of the more solid bones of the jaw become filled up solidly with fine gravel, often cemented, and sometimes holding pellets of gold. Bones found in river gravels show the effects of attrition and wearing. All the thin plates, asperities, and sharp edges disappear under the violence to which they are subjected in running water transporting gravel.

In the Calaveras skull no such conditions are found. It was found hollow, nearly empty as left by the decomposed brain, not filled with gravel or sand, of a river deposit, and the broken edges were sharp and not abraded. This condition alone is sufficient evidence that the skull and the gravel in which it was said to occur were not parts of the same deposit and contemporaneous in origin in the river bed.

But certain objects were found in the skull—other bones, an ornament of some kind, and the shell of a snail, partially cemented together and to the skull by a deposit of calcareous tufa. All these objects indicate surface origin and interment, and their presence is not reconcilable with any theory of the entombment of the skull in auriferous, deep-seated gravel.

Since the exhibition of the skull at Chicago a full description of it, illustrated by a full-sized drawing, has been published by Professor Whitney.[1] By reference to this drawing it will be seen that all the fractured edges of the bones (for it is not an entire skull) are sharp and angular, and do not show signs of abrasion.

[1] Contributions to American Geology, Vol. I. The Auriferous Gravels of the Sierra Nevada, California, by J. D. Whitney, 4to, Cambridge [U. S.], 1880.

The presence of calcareous tufa is adverse to the theory of the occurrence of the bone in the deep gravel. The tufa is an incrustation; its presence indicates surface evaporation and concentration of calcareous waters. It does not occur in this case as a permeating solution forming a cement for deep gravel, but as an investing crust deposited on and around the bone, although it is claimed that a chemical change in the bone has resulted. The cementing material of the deep gravels is generally siliceous rather than calcareous, or if calcareous it permeates the mass and unites the pebbles and grains of sand into a rock-like mass.

The description states: "In cutting away the mixed tufa and gravel which covered the face and base, several fragments of human bones were removed, namely, one whole and one broken metatarsal; the lower end of a left fibula and fragment of an ulna as well as a piece of a sternum." "These bones and fragments of bones might have belonged to the same individual to whom the skull had appertained, but besides these there was a portion of a human tibia of too small size to be referred to the same person." There were also fragments of the bones of a small mammal. Under the molar bone of the left side, a small snail shell was lodged, partially concealed by one of the small human bones which was wedged into the cavity. This shell was recognized by Dr. J. G. Cooper as *Helix mormonum*, a species now existing in the Sierra Nevada. Cemented to the fore part of the roof of the mouth was found a circular piece of shell four tenths of an inch in diameter, with a hole drilled through the center which had probably served as an ornament. Several very small pieces of charcoal were also found in the matter adhering to the base of the skull."[1]

I have given this full quotation that there may not be any mistake. Professor Whitney is certainly to be commended for his complete presentation of evidence which is sufficient, in my judgment, to show that he was dealing with the relics of an Indian burial place rather than a fossil from the ancient gravels. It is not possible to conceive that this mixture of human bones

[1] *Ibid.*, p. 268.

of portions of at least two individuals, an ornament, charcoal, and a snail of an existing species, or of any species—a thin fragile shell—could travel together in the bed of a river and be concentrated in one spot, in fact, in one mass. It is incredible.

Much stress in the discussion upon the authenticity of this relic is placed upon the statement of the miner that he found the skull in his mine; that he found it there lying on the side of the channel with a mass of driftwood. While this statement of finding bones and driftwood together at that depth tends to discredit the statement it may be accepted, but with the question, how did the skull get there? The best explanation is found in the statement of another miner who had a claim in the vicinity that in going home one evening he picked up the mass, and, in passing his neighbor's shaft, threw it down to frighten him, and get him to go home to supper. The skull was then "discovered" and taken to Angel's Camp, where, after resting for a time in the window of the apothecary, it attracted the attention of Dr. Jones, of Murphy's camp, and was made known to the scientific world.

This is the story as told to me by eyewitnesses and participants. Thus the silent but convincing testimony of the skull itself, and of human testimony, are against its reception as evidence of man's antiquity.

But while the authenticity of this skull as a Pliocene fossil is questioned and challenged by most authorities, it is often accorded a quasi-recognition rather than an unqualified rejection. For example Professor G. Frederick Wright relying partly upon new evidence presented by Mr. Becker at the meeting of the Geological Society of America in 1891 appears to be convinced of the genuineness of the skull and states "it would seem unreasonable any longer to refuse to credit the testimony."[1]

The most satisfactory and common-sense discussion of the merit of this skull as evidence with which I am acquainted is that by Principal Dawson in his work enitled *Fossil Men.*[2] After

[1] WRIGHT, Man and the Glacial Period, p. 296.

[2] Fossil Men and their Modern Representatives, by J. W. DAWSON, LL.D., F.R.S., F.G.S., Montreal, 1880, pp. 344–347.

giving five cogent reasons for the non-acceptance of the Calaveras skull as evidence of the existence of man in Pliocene times he sums up as follows: "The above reasons are, I think, quite sufficient to warrant any geologist in declining to accept the human remains of the California gravels as other than those of American Indians of modern periods."

Quatrefages makes two references to the Calaveras skull. In one he writes: "Much has been said about the skull discovered by Whitney in California. Unfortunately, the description of this specimen has not appeared so that doubts have on several occasions been expressed as to the existence of the fossil itself. The recent testimony of M. Pinart has removed them, but has at the same time created the most serious doubts as to the antiquity of this specimen, which seems to have been found in disturbed grounds."[1]

Again, in discussing the succession of the two great types of skulls, he states "that at present everything argues in favor of the anteriority of the dolichocephali. In America the only known fossil skull leads to the same conclusion."[2]

In the foregoing citation of the conclusions of Dr. Dawson it will be noted that he groups together the evidence presented by the skull and those from other human remains in the California gravels. This tendency is shown, also, by Dana, who, after mentioning the doubts of the authenticity of the skull, writes: "Whitney also mentions the discovery of flint implements in the auriferous gravel in other parts of California. The fossil plants of the gravels are referred to the Pliocene (or partly Miocene) by Lesquereux. The few mammalian remains include the Champlain mastodon and elephant, but in some places Pliocene species. Some recent land shells were contained in the earth filling the cranium."

To anyone not familiar with the localities, the modern and ancient gravels, and the occurrence of flint implements, the

[1] A. DE QUATREFAGES, The Human Species. Int. Sci. Series, D. Appleton & Co., 1888, p. 291.

[2] Ibid., p. 299.

conclusion would, I think, be a fair one that both the mammalian remains and flint implements occur in the same gravels, or horizon, in which the skull is claimed to have been found. So far as my knowledge extends this is not so. I am not aware that it has been claimed that flint implements, or even the remains of the mammoth and the mastodon have been found where the skull was said to occur. That flint implements have been found in association with the remains of the large mammals there is little doubt, but as to the age of such gravels, and whether or not the implements may not have been washed in from higher levels or superficial deposits of a far later origin I am not able to bear conclusive testimony. The subject requires most careful and extended investigation, the fact being always kept in mind that in the gigantic placer mining operations of California there is a concentration upon the bedrock of all heavy objects which may have been originally in the surface soil or any part of the banks of gravel between the soil and the bed of the ancient river.

In all river and creek channels of modern streams, and even in what are called dry arroyos or gulches, there is a possibility that in seasons of flood or of great accumulation of rushing water from showers or cloud-bursts objects lying on the surface, such as stone implements, pestles, mortars, metates, flint chips, etc., may be swept onwards in the gravel and sunk to the very bedrock and become buried by deposits twenty feet thick, and possibly more and all in the space of an hour or less. The loss of iron safes in different places in California and Arizona, the safes wholly disappearing, and similarly the loss of quicksilver in flasks while crossing a swollen torrent are familiar examples. Heavy objects, like gold, in swiftly moving water are carried to the lowest point possible and are covered from view by heavy deposits of gravel and bowlders. The finding, therefore, of Indian stone mortars at a considerable depth in gravel in a modern stream valley is not good evidence of antiquity.

In regard to the concentration of objects on the bedrock of placers, when there is sluicing or washing by the hydraulic method on a large scale, miners are familiar with the fact that

nails, spikes, shot and bullets are frequently found in cleaning up the sluices. In one instance, known to the writer, a small cast-iron casket containing the remains of an infant in alcohol was found in cleaning up a sluice after a long run by the hydraulic process upon a bank of gravel some thirty feet deep.

THE TABLE MOUNTAIN RELICS

Much has been written regarding the flint implements in great variety and perfection of workmanship collected from Table Mountain near Angels Camp by the late Dr. Snell. It was stated by him that they were found under Table Mountain, the lava cap of an old Pliocene river. I must confess to have for a time lent credence to this view of their occurrence. I reported the facts as I then understood them at the Congress of Archæologists at Paris in 1867.

But later investigations have satisfied me that these relics were entombed in the surface soil and accumulations of the slope of the mountain just below the jutting, overhanging cliffs of the lava, which afforded excellent protection from the weather, and were no doubt occupied as habitations or dwellings analogous to the cliff-dwellings of New Mexico and Arizona, but without any, now visible, exterior wall or construction. There is no reason for associating these flint implements in any way with the occurrence of the skull, or with the bones of the great mammals.

WM. P. BLAKE.

UNIVERSITY OF ARIZONA,
March 1899.

A GRANITE-GNEISS IN CENTRAL CONNECTICUT

THE granite-gneiss[1] to be described occurs on both sides of the Connecticut River, some five miles east of Middletown. It cuts the schists of the eastern crystalline area of Connecticut, a short distance east of their contact with the Triassic sandstone. Its distribution is shown on the accompanying map (Fig. 1).[2] It forms an oval area in the mica schist, and, at its northern end, is continued northward by a series of beds varying from a few inches to many feet in thickness, lying parallel to the enclosing schists. The largest of these is a direct continuation of the main granite-gneiss mass, and all are probably parts of the same intrusion. As the distance from the main area increases, these beds gradually thin out and disappear from the schists.

The only previous work on the geology of this region is that of Percival,[3] who recognized this granitic rock only on the east side of the river, and united that part of it with a large mass of granitic-gneiss to the north, with which it is probably not connected. He does not consider the origin of any of the gneisses. It has not been possible to use Percival's results except in a general way, and the work done in this region by the writer is essentially *de novo*.

The rock is a medium to fine-grained biotite-gneiss. The color varies from white or light gray to dark gray, according to the amount of biotite. In a few cases the rock is almost or quite massive, but usually it is well foliated. The granite-gneiss is cut by several sets of joint planes, of which one set is nearly

[1] In this paper a gneiss of granitic composition and of unknown origin is called a granitic gneiss; if of igneous origin, a granitic gneiss. See C. H. GORDON in Bull. Geol. Soc. America, Vol. VII, p. 122.

[2] That portion of the western boundary of the granite-gneiss north of the river is largely covered by river terrace, and for about a mile along the eastern border, near Great Hill pond, outcrops are rare. With these two possible exceptions, the "supposed boundary," so-called, is believed to be very nearly the true boundary.

[3] J. G. PERCIVAL: Report on the Geology of Connecticut. 1842, pp. 222, 224.

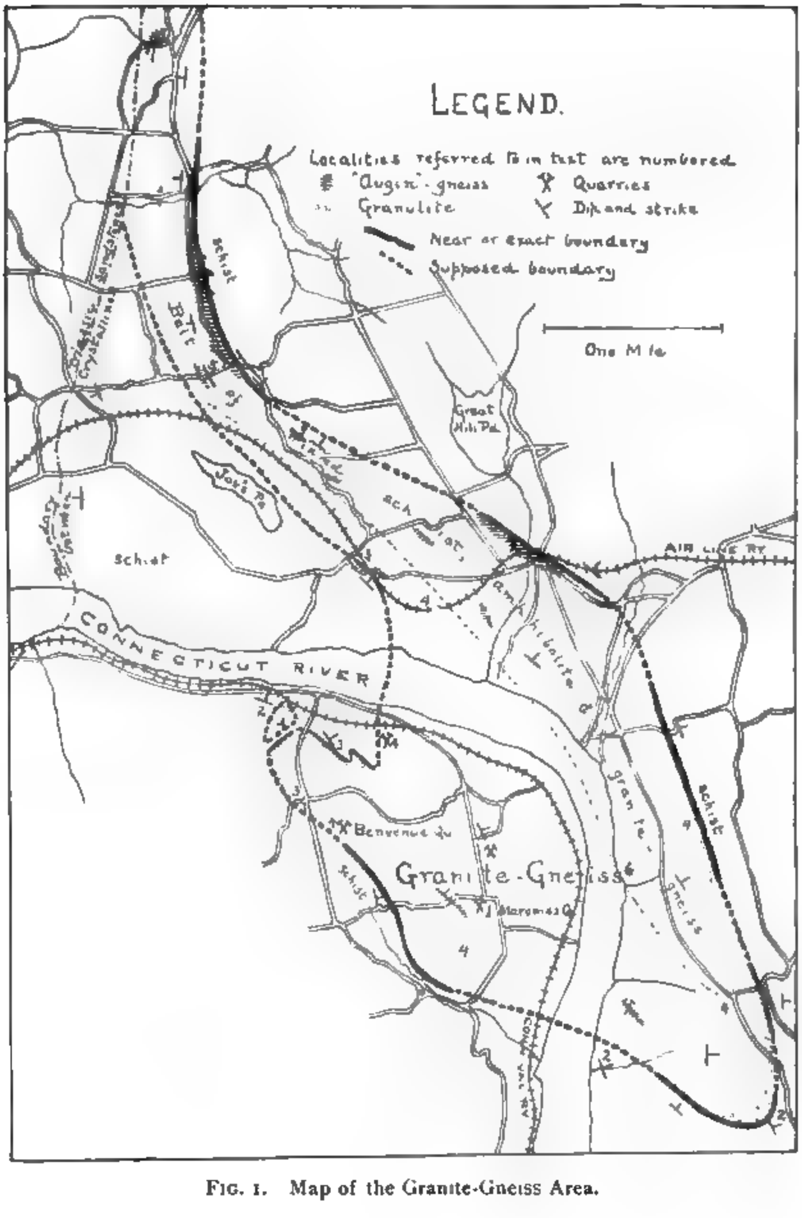

FIG. 1. Map of the Granite-Gneiss Area.

[illegible] parallel to the [illegible] giving the rock a banded appearance (Fig. [illegible], Map [illegible]). Several quarries have been opened and the attempt has been made to market the rock as a building stone. It is handsome when first quarried but stains badly and so is used only for foundations, etc.

[illegible]

[illegible]

ıe same origin as does the general form of the area. At ɜveral points, too, along the western border and southern end f the granite-gneiss (Map, 2), the line of contact cuts across ıe strike of the foliation of the enclosing schists. This is not oticeable at all of the localities at which actual contacts between ıe two rocks can be seen, though it is at one or two, but it omes out on mapping the dip and strike of the schist. This ɔliation of the schists seems to be a stratification foliation and ot a secondary structure, because (1) it is parallel to the alterating beds of schist and fine-grained micaceous gneiss which ıake up the schist formation, and (2) the dip and strike of the ɔliation is not uniform throughout the area, but varies through ll possible changes.

2. *Contact Phenomena.* — At some of the localities where the xact contact of the two rocks is seen there is the clearest proof 'ithin narrower compass of the eruptive character of the granite-neiss (Map, 3). The line of contact is frequently irregular, the ranite-gneiss often cuts across the foliation of the schist or ɜnds tongues into the schist; and sheets of schist, partly torn 'om the main schist mass, occur projecting into the granite-gneiss.

As the granite-gneiss occurs in the midst of completely crysılline schists, any considerable contact metamorphism of the ırrounding rocks would not be expected. In many granite ıtrusions into crystalline rocks no contact metamorphism is ɜen. In the present case besides quartz, feldspar, biotite and ccasionally hornblende, the schists carry at times garnet, :aurolite, cyanite and tourmaline. The latter often seems to be ɔnnected with the pegmatite dikes which cut the schist. None f these less common minerals is more abundant near the conıct or can be considered a result of the metamorphic action of ıe granite-gneiss.

It is sufficient merely to mention at this point another evience of the igneous character of the granite-gneiss, namely, the ne-grained granulitic character which it assumes at some points ɔout its border. This endomorphic metamorphism of the ranite-gneiss will be described more fully below.

3. *Inclusions.*— One of the most striking character of the granite-gneiss is the pre: schist within its boundary. These are localities in widely different parts of the not far from the border (Map, 4). They inches to many feet in length, and may irregular form. The material composing t or a fine-grained biotite-gneiss, similar to t the gneiss and often showing the minute f is characteristic of the latter. The inclu: more massive and in the more foliated va gneiss, and also in the granulitic facies points about the border.

At this point it is well to describe while not a proof of the igneous origin is best understood in connection with i localities in the southern half of the grani bands of schist of uniform thickness, r foliation of the immediately adjacent cease at a greater or less distance, but th cannot be seen because of lack of outcro contacts with the enclosing granite-gneis cases tongues of the latter enter th showing them to be inclusions. And as e which do not show an apparent eruptive area of rock which is certainly in largest p likely that all such occurrences are inclusi inclusions vary from a few feet to several ness, and are sometimes several hundred direction is variable and is independent schist lying nearest to them outside of tl Their sheet-like character was evidentl strong foliation of the schists through whi here eruptive. It is, however, along the e gneiss that the amount of this foreign Here the mica-schist is associated wi

thin-bedded gneiss and schist which contain both biotite and hornblende, and with amphibolite. These dark bands of gneiss and schist are not here variable in direction, but run parallel to the boundary of the granite-gneiss, and agree in dip and strike with the schist east of it and with themselves. Yet undoubted igneous contacts occur between these dark gneisses and schists, and the lighter granite-gneiss which occurs between them. The granite-gneiss which in other parts of the area replaced almost entirely the schist through which it came, here merely forced its way into fissures parallel to the foliation of the country rock. The distribution of this belt of mixed rock is shown on the map. As already pointed out the granite-gneiss gradually disappears as we go north.

4. *Schlieren.*—In a number of places where the granite-gneiss is most massive, it encloses patches of darker material or schlieren—basic segregations of the granite magma. These are best seen in the Benvenue and Maromas quarries. The schlieren are of uniform composition, finer grained than the enclosing rock, have a larger proportion of biotite, and often contain hornblende, which is almost wholly wanting in the ordinary granite-gneiss. They are rounded, elliptical or irregular in outline and always elongated parallel to the foliation so as to form lenticular patches and in extreme cases bands. This lenticular and frequently sheet-like form is probably due to movement in the partly differentiated magma previous to thes olidification of the rock. Such darker and more basic portions are very common in granites and have been regarded as a strong indication of the eruptive origin of the rock in which they are found.[1] In the Benvenue quarry where these schlieren occur, the rock also holds irregular inclusions of schist.

Associated Pegmatite Dikes.—Although the presence of abundant pegmatite dikes about a granitic area would not in itself be a proof that the rock in question was eruptive, it would be an interesting and corroborative fact. In the opinion of

[1] ROSENBUSCH: Massige Gesteine, p. 62; G. H. WILLIAMS, XV., Ann. Rept. U.S. Geol. Surv., p. 662.

Brögger,[1] Williams,[2] Crosby,[3] and others, the presence of one or more parent masses of less acid plutonic rocks is to be expected in such regions of abundant pegmatite dikes. The pegmatite dikes of central Connecticut are abundant, and are widely known for the variety and beauty of the minerals they have furnished collectors. They occur in dike-like masses in both gneisses and schists, but more abundantly in the latter, and they both cross and run parallel to the foliation of the enclosing rocks. Their contact with the gneisses and schists is sharp and they frequently contain inclusions of the same. There are two other considerable areas of granitic biotite-gneiss in the region, one to the south and the other to the north of the area under consideration. The former shows no sign of igneous origin and seems to be the basal member of a series of conformable gneisses and schists which form a northward pitching anticline. The study of the latter area is not yet completed. The evidence so far collected seems to indicate that it is largely composed of eruptive material; but even so the Middletown granite-gneiss is more centrally located with reference to the dikes and would more likely be the rock genetically connected with them. The schists which surround it are more filled with pegmatite. The hills near the Connecticut River, just west of the granite-gneiss, are known as the "White Rocks," from the prominent outcrops of pegmatite, and the schist east of the granite-gneiss is also cut by quantities of the same rock. This abundance of pegmatite dikes would lead us to expect one or more centrally located masses of granite with which they could be connected, and the area of granite-gneiss we have been describing seems to answer the expectation It does not appear that the dikes radiate from it; rather they follow in a general way the foliation of the schist. They do, however, appear to grow more abundant toward the granite-gneiss.

In connection with the evidence brought forward to show the eruptive nature of the granite-gneiss it is interesting to know

[1] Zeit. für Kryst., Vol. XIV, 1890, or Canadian Rec. Sci., Vol, VI, p. 33.

[2] Fifteenth Ann. Rept. U. S. Geol. Surv., p. 680.

[3] CROSBY and FULLER, American Geologist, Vol. XIX, p. 151.

that the granitic biotite-gneiss to the south, which has already been mentioned as constituting the lowest member of an anticlinal fold, and which appears from its field relations to be a sedimentary rock, wholly lacks the various characteristics of igneous origin possessed by the granite-gneiss. The mineralogical and structural characters which come out in a microscopical study of the rock, and which will be described below, are also in harmony with the belief that the granite-gneiss, in spite of its general and pronounced foliation, is an igneous rock.

II. PETROGRAPHY OF THE GRANITE-GNEISS

1. *The ordinary type.*—The ordinary form of the granite-gneiss is a light-colored, rather fine-grained biotite-gneiss. The amount of biotite varies considerably. Where it is most abundant, the rock is a dark-gray, well-foliated gneiss; where least abundant, the rock is light-gray and of a quite granitic appearance. In no case does it become perfectly massive. The grain of the rock allows of its being split along the foliation into curbstones, but not, as in the case of some of the other gneisses of the region, into flagstones. In the main body of the granite-gneiss the strike of the foliation is approximately N. 45° W.; the dip, 30° N. E. Joint planes cut the granite-gneiss in several directions, one nearly or quite parallel to the foliation, others at right angles. The rock is handsome when first quarried, but has proved useless as a building stone, because it rusts on exposure.

Microscopically the rock is a granitic mixture of feldspars and quartz, in which lie small plates of biotite. The biotite is abundant, generally with a pronounced parallel arrangement, to which the foliation of the rock is due. Hornblende is almost wholly absent. In a single section green hornblende occurs in amount subordinate to the biotite and it can be seen in a very few exposures in the field. The feldspars usually present an allotriomorphic, granitic aggregate of grains. Orthoclase is most abundant. An acid plagioclase is of common occurrence. Microcline also occurs in smaller and more irregular grains.

Both orthoclase and microcline frequently show a fine microperthitic intergrowth, with a second feldspar. In a larger number of sections some orthoclase and plagioclase grains show a granophyric intergrowth, with a second mineral, probably quartz, which takes the form of narrow irregular, curving or angular inclusions, converging toward the center of the feldspar grain. This granophyric intergrowth is absent from the probably sedimentary gneisses to the south, and seems to be characteristic of those of igneous origin. Quartz occurs in irregular but somewhat rounded interstitial grains, and is also common in droplike inclusions in the feldspars, which occasionally approach a a dihexahedral shape. Titanite, in small, rounded, and lenticular grains, is the most common accessory. A very little apatite and magnetite occur. In about one half of the sections there is evidence of a slight amount of crushing. In the section where this is best shown, some of the quartz grains have been elongated, broken into separate areas, and granulated about their border and along lines of fracture; and between the feldspar grains are lines of smaller grains, which seem to have come from the fracturing of the feldspar. Yet in this section considerable portions show no evidence of crushing, and in many slides no proof of crushing exists.

2. *Schlieren.*—The biotite-gneiss, especially where it is more massive, often contains schlieren of darker color and finer grain, which have already been referred to and partly described in the discussion of the igneous origin of the granite-gneiss. Sections from these schlieren resemble closely the ordinary granite-gneiss. They are granitic in structure, but with a distinct foliation. Green hornblende is present, but is less abundant than the biotite. Orthoclase, plagioclase, and microcline occur in abundance in the order named. A few feldspar grains show the granophyric intergrowth already mentioned. Quartz and microperthite are absent. Titanite is a common accessory. The presence of hornblende and absence of quartz, while keeping the other essential structure and characters of the granite-gneiss, indicates that these darker patches are an integral part of the

granite-gneiss, only somewhat more basic than the general rock. The absence of any evidence of crushing in the sections shows that their present lenticular and banded form was attained while the rock was still unsolidified.

3. *The "augen"-gneiss.*—Frequently the granite-gneiss becomes a decided "augen"-gneiss. Its distribution is indicated as nearly as possible on the map. It attains its best development along the northeastern border of the granite-gneiss and in the narrow tongue that runs north into the schist. The "augen"-gneiss often passes gradually into the ordinary granite-gneiss, with which it is identical in mineralogical composition and in structure, with the single exception of the occurrence of sub-porphyritic feldspar crystals and aggregates. A surface broken at right angles to the foliation shows a light gray gneiss, dotted with more or less distinct "augen" of white or pink feldspar, averaging three fourths of an inch in length, and with a parallel arrangement, around and between which run the lines of biotite flakes. The feldspar of the "augen" often reflects light as a single crystal, either simple or a Carlsbad twin, and rarely this crystal is roughly rectangular, yet it never possesses crystal boundaries. Quite commonly the cleavage surface of these broken crystals shows dull rounded areas of feldspar which are differently oriented grains included within the larger crystal. Where a single crystal occurs it forms the irregularly margined core of the "auge" and is surrounded by a dull white rim composed of an aggregate of fine feldspar grains. As the core is pink and the rim white, there is a further contrast between the two. Much more often than not, however, the reddish core does not reflect as a unit, but consists of an aggregate of grains, still flesh-colored and coarser than the rim. In other cases the "augen" consist of aggregates of white feldspars without any reddish cores.

It looks very much in the hand specimen as if those reddish cores of the "augen," which are composed of an aggregate of grains, were derived from the fracturing of single grains, which in some cases seem to remain partly intact at the center. But

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seen to be composed of feldspars of
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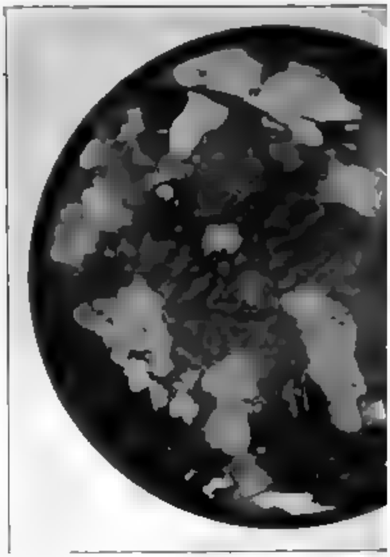


FIG. 3.—An "auge" of the "augen"-gneiss (
upper right side is beyond the border of the section.
of clear feldspar grains with a little biotite.

the central orthoclase grain. About this
a zone of clearer feldspars. The red core
both single grains and aggregates, are o
The case may be somewhat different wit
in many cases surround the red cores.
evidence of crushing, and may be in pa
eral crushing of the red cores, possibly
recrystallization, for the feldspars here ha

than those in the central part of the "augen." Yet the absence of evidence of extensive crushing, and the fact that many of the "augen" consist wholly of white aggregates of feldspar which under the microscope show no evidence of crushing, lead us to suspect that even these white aggregates, which sometimes occur as borders around the red cores and sometimes constitute "augen" by themselves, may be, in large part, original crystallizations. The fact that these "augen" do not include to any extent plates of biotite, but that the lines of biotite flakes curve around them, seems to point to the formation of the "augen" previous to the complete solidification of the rock. The "augen"-gneiss, like the granite-gneiss of which it is a local variation, is of igneous origin. If we suppose that the first step in its formation was the separation of small orthoclase individuals or aggregates of feldspar, mainly orthoclase, but containing plagioclase and microcline, which received their parallel arrangement before the final solidification of the rock, and which may have been subsequently somewhat reduced by crushing, we shall have the most probable explanation of the "augen"-gneiss phase of this granite-gneiss.

The foliation of the granite-gneiss does not seem to be in the main a dynamic result. Evidence of crushing is found in many sections in the form of wavy extinction of the quartz and lines of finer material between the larger quartz and feldspar grains, and crushing may be responsible in part for the parallel structure of the rock. Yet in many sections of the well-foliated gneiss the microscope shows no evidence of crushing at all. It seems more likely that the arrangement in a common plane of the biotite and, in the "augen"-gneiss, of the often rather tabular grains of orthoclase is a result of movement in the partly solidified magma. The character of the schlieren points to the same conclusion. In ordinary granites the schlieren are not stretched, but are roughly equidimensional, and such we may suppose their original form to have been in the present case. Had they been drawn out to their present distorted condition subsequent to the solidification of the rock, they could hardly

fail to show evidence of such a movement in the distortion and crushing of their individual mineral particles, but such is not the case. And a rock subjected, while still incompletely solidified, to such an extensive movement as is indicated in the present instance by the form of the schlieren, would naturally have the elements which had already crystallized out, in this case biotite and, locally, individual grains and aggregates of feldspar, arranged in a more or less parallel manner.

4. *Granulite.*—For a mile along its western border, and for a somewhat greater distance about its southern end, the granite-gneiss shows a granulitic facies towards the contact. At other points both the "augen"-gneiss and the ordinary granite-gneiss may occur unchanged in immediate contact with the schist. The width of this granulite border is not constant; it varies from two or three feet to many yards. Where typically developed, it is a fine-grained, light gray or brownish rock, sometimes pure white and lacking all traces of dark minerals. This pure white granulite is present only at a few places and immediately at the contact. Small garnets are usually present. The rock has asugary texture, and when somewhat weathered often crumbles under the pressure of the fingers. Microscopically it is a fine-grained aggregate of orthoclase, an acid plagioclase, microclineand quartz. The structure is the so-called granulitic of M. Levy[1] and the panidiomorphic of Rosenbusch.[2]

The quartz and feldspar form an aggregate of variously oriented rounded grains of uniform size, which are not, however, bounded by crystal planes. With the scarcity of biotite, the foliation becomes indistinct or wanting. In one case garnet grains form fine lines on the broken edge of the rock. No evidence of crushing exists.

[1] M LÉVY: Classification des Roches Éruptives, p. 30.

[2] ROSENBUSCH: Massige Gesteine, p. 461. In this connection see TURNER: Geology of the Sierra Nevada, Sixteenth Ann. Report U. S. Geol. Surv., Pt. I, p. 737. Granulite (M. Lévy) is synonymous with aplite (Rosenbusch). Rosenbusch regards aplites as typically dike rocks, yet recognizes their occurrence as acid border phases of granite intrusions. *Ibid.*, p. 65.

At several localities the granulite can be followed from the tact and can be seen to pass gradually into the ordinary ıite-gneiss. The changes on passing from the contact are as ɔws : (1) The rock becomes coarser, loses its granulitic cture and assumes a granitic structure. (2) The garnet dis-ears, biotite becomes abundant and is accompanied by the nary accessories of the granite-gneiss, titanite, magnetite and tite. (3) Small grains of granophyre and microperthite

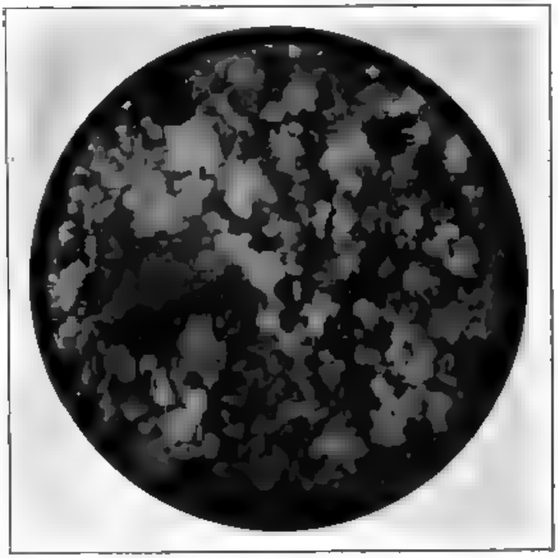


FIG. 4. Granulite (×18).

ear. These are common among the feldspars of the granite, are wholly lacking in the granulite. Of these characters the ıulitic structure and the presence of garnet extend farthest n the contact and often at a distance of many yards the ly biotitic granite-gneiss becomes garnetiferous and shows a idedly saccharoidal texture.

Bands of granulite occur interbedded with or cutting across schists near the contact. These bands are often less than an ı in thickness, and may connect with the main mass of the

granulite. A few of the smaller bands contain much muscovite and are well foliated. The granite-gneiss sometimes assumes a granulitic facies about inclusions. A good example of this occurs at one end of the Benvenue quarry, west of the river. A fifteen-foot mass of schist is caught in the granite-gneiss, which is dark gray and thick-bedded, but at the contact with the schist-inclusion changes to a fine-grained, white granulite with minute scattered flakes of biotite.

The eruptive nature of the granulite is clear. It cuts across the bedding of the surrounding schists; it sends apophyses into them; it holds inclusions of them. That it forms one geological body with the granite-gneiss is shown by its gradual passage into the latter at several points. It is not a crushed granite, as its position about the border of the granite and the absence of any microscopical evidence of crushing would show. It is an example of original endomorphic contact-metamorphism of the granite-gneiss,—more acidic and finer grained than the main body of the rock. The fineness of grain and the granulitic structure may be due to more rapid cooling of the magma in the neighborhood of the contact, though there is no reason why the conditions and consequently the structure of the granite-gneiss should be different at these points from what they were about the whole border of the granite. The more acidic character of the rock at the contact has not been satisfactorily explained. Similar phenomena have been observed elsewhere,[1] notably about some of the granite intrusions of France.

Besides the contact granulite described above, granulite occurs in three distinct forms. It occurs (1) as bands, generally not over a foot in thickness, cutting the granite-gneiss in or across the foliation and often becoming coarser and somewhat pegmatitic. In many cases these bands appear to grade somewhat abruptly into the surrounding rock. They are in a sense later than the granite wall-rock and may mark a closing stage of igneous activity, before the granite had fully hardened. It

[1] ROSENBUSCH, Massige Gesteine, p. 65. References to articles by BARROIS on several of these granites are given on p. 14.

occurs (2) as a white, fine-grained granulitic portion of some of the pegmatites. (3) One or several dikes of gray granulite cut the dark gneisses which occur associated with the granite-gneiss along its northern border (Map, 5). Their position is shown on the map. Each of these varieties has its own peculiarities and all differ from the contact granulite. They are probably all later than this last and are merely mentioned here for the sake of completeness.

5. *Darker and more foliated granite-gneiss.*—Along the northeastern side of the granite-gneiss area is a belt which has already been noticed, in which the granite-gneiss alternates with schists and with dark, more or less hornblendic gneisses and amphibolites. This area is indicated on the map. Associated here with the granite-gneiss and with these other rocks is a third type, in a way intermediate, yet more closely related to the granite-gneiss. These last rocks are darker and more foliated than the granite-gneiss. They are frequently marked by lenticular-linear white patches, up to a third of an inch in thickness, composed of an aggregate of feldspar grains. From this character they may be named "spotted-gneiss." They agree microscopically in structure and in mineral composition with the granite-gneiss. There are only two differences: (1) an increase in the amount of biotite and, as a consequence, a better developed foliation, and (2) the presence in some cases of hornblende. Sometimes they show microscopical evidence of crushing. They form eruptive contacts with the schists which are cut by the granite-gneiss.

The relations of the spotted-gneiss and the amphibolites are not wholly clear, and these relations are probably different in different cases. The two rocks are distinct petrographically. The contact between the two is an eruptive contact. If the amphibolites are older—and their stronger banding and foliation might well suggest as much—it matters not to the understanding of the granite-gneiss whether they are of igneous or sedimentary origin; they are in either case earlier rocks cut by the granite-gneiss. But in many cases they are probably later.

For eruptive amphibolites occur abundantly in the schist and presumably sedimentary gneisses outside the granite-gneiss area, and at one point within the granite-gneiss (Map, 6) banded amphibolites occur grading into massive hornblende-gabbro, and this basic rock becomes finer grained toward the contact where it cuts across the foliation of the granite-gneiss. Some of these amphibolites, then, are certainly younger than the granite-gneiss and cut it. Some may be older than the granite-gneiss.

The relation of the spotted-gneiss to the more ordinary granite-gneiss is not altogether clear. In some cases parallel bands of the two lie in sharp contrast. Again within limited areas a complete series of intermediate rock types occur. The spotted-gneiss seems to be a somewhat more basic rock derived from the same magma as the granite-gneiss. In part, however, it looks as if the two were not strictly contemporaneous. The spotted-gneiss may have been intruded into the granite-gneiss, or *vice versa*, although both find their origin in the same molten body and were the products of a single igneous intrusion.

LEWIS G. WESTGATE.

OME NOTES ON THE LAKES AND VALLEYS OF THE UPPER NUGSUAK PENINSULA, NORTH GREENLAND[1]

INTRODUCTORY STATEMENT

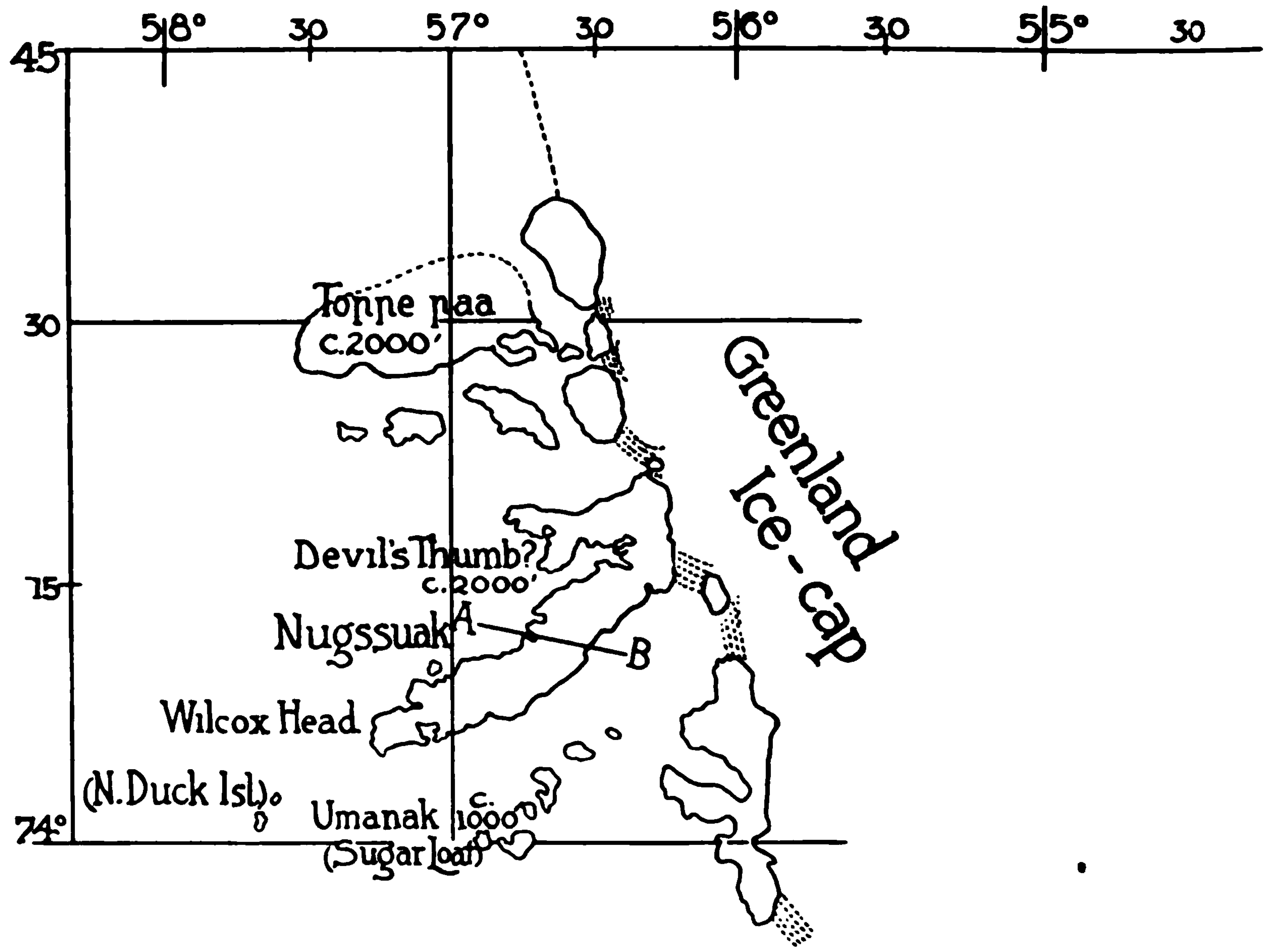
THE Upper Nugsuak peninsula is located in north latitude 4° 5′–15′; is 25 to 30 miles long, averaging from four to .x miles in width, and has a due southwest trend with the general oast line of Greenland. This part of the coast is characteristi-ally rough and rugged. The marginal strip—at present ice-:ee—is intersected by numerous fjords, which, in many cases, enetrate to the very edge of the ice-cap, cutting the uncovered ınd into numerous islands and peninsulas. A considerable part f the uncovered lands is occupied by lakes.

The peninsula is limited on its north and south sides, by fjords escending to depths of not less than 300 to 500 fathoms, and aries in elevation up to nearly 3000 feet. The hilltops have a ·eneral elevation of 1000 to 2000 feet. Its surface is a very ough and irregular one; is cut up by a network of deeply incised ·alleys, the seaward extension of which add to the ruggedness ·f the coast line.

The general appearance of the inter-valley areas—hills and idges—is that of a well rounded moutonnée form, which pre-·ailingly show among the lower hills a highly polished sur-ace, while the higher peaks are as uniformly angular, and are ·ery much less subdued topographic types. Some of the valley ·lopes are steep, often times precipitous, often with large talus

[1] The writer wishes to express his indebtedness to the Cornell University Expedi-ion of 1896, under the directorship of Professor R. S. Tarr, and of which the writer ras a member, when this work was made possible. Further acknowledgments are lue Professors R. S. Tarr and A. C. Gill, and Messrs. E. M. Kindle, J. O. Martin and . A. Bonsteel for valuable aid and suggestions — especially Professor Tarr, who kindly ead and criticised this paper in manuscript.

heaps at their bases. The slopes have been trenched and furrowed by running water derived from the melting ice and snows. The scarred and shattered surface everywhere testifies to the great rapidity of frost action. The results of glaciation are conspicuous over all its parts, attesting the fact that the ice-cap has over-ridden its entire surface at some previous time. Remnants of local glaciers still exist among the higher peaks of its north-



ern border. Bowlders are abundant, while the paucity of till is quite marked.

Owing to much variation in texture, the intimate relationship of rock structure to topography is well marked, as shown in the case of the dikes of basic rock — diabase (?) — found cutting the gneiss in various directions. The gneiss has been intricately folded and contorted.

LAKE CLASSIFICATION

No large lakes are found on the peninsula. The basins vary in size from one and a half miles in length down to the merest

pool. The largest water bodies are confined for the most part to the large valleys; but many tarns are scattered over the higher lands. Both types are, with one or two possible exceptions, true rock-basins, since they are entirely surrounded by rock in place; for there is rarely enough till for a dam. Based primarily on origin, the lakes are grouped under "Rock-basins due to glacial origin," and on position, are further grouped as (*a*), highland, and (*b*), valley lakes.

ROCK-BASINS OF GLACIAL ORIGIN

The highland lakes.—On account of their salient features, not all the highland lakes can be ascribed as the direct products of glacial erosion; but it is certain that all of them owe their origin, either entirely or in part, to glaciation. Therefore, since this class is in part directly and in part indirectly the products of glaciation, and since no differentiation of those that are ice-scoured basins from those that are perhaps only partially due to glaciation, can be effected, they are both grouped as highland lakes of glacial origin.

This entire group of lakes is composed of small tarns and pools of very shallow depth. Their distribution is apparently controlled entirely by the weaker rock structure. Where the joint planes were numerous and intersected, tiny lakes were often found. Generally, the larger highland basins were found developed in the direction of the strike of the gneiss, and had resulted from the removal of the softer layers of gneiss, by some process of erosion. Still others were observed where these planes of weakness were not apparent, but, in some cases, could probably be ascribed to the result of chemical or mechanical weakness, due to mineral distribution. The lakes are prevailingly irregular in outline, and contain varying amounts of weathered débris scattered over the bottoms of their basins, which is very probably due to recent action.

Their size, distribution, position and intimate relationship to rock structure, and irregularity of outline are sufficient evidence of their having resulted, in part, from differential atmospheric

erosion. Scarcely any doubt exists against the large share of these tarns having resulted directly from differential ice scouring along the line of weaker rocks. In other cases, however, the basins have been more or less modified by the ice advance, which served to remove the preglacial decay, resulting in some instances, in a probable deepening from this cause.

Evidence has been brought forward by others, proving that not all trace of minor preglacial form was destroyed by the ice advance over portions of this and the Baffin land coast. Furthermore, that in its advance, all the preglacial decay was not removed, but that a somewhat roughened and irregular surface resulted from such action, mostly along the lines of rock weakness. To the combined action, therefore, of differential preglacial weathering and ice erosion, along the lines of weak structure, are due most, if not all, of the group of highland lakes.

Concerning the origin of this type of lake along the Greenland coast and other similarly glaciated lands in the arctic latitudes Professor Tarr says:[1]

> It is noticeable near Cumberland Sound, as well as in Turnavik, and in Hudson's Strait, and indeed in Greenland, that there are many basins of small size, surrounded entirely by rock. While some of these have no doubt been scoured out by differential ice erosion, the position of many of them along the lines of weaker rocks, indicates that they represent differential preglacial weathering. The advance of the ice in these cases has served to remove the

[1] TARR, R. S.: Amer. Geol. 1897, Vol. XIX, pp. 195, 196.

decayed rock, and perhaps to deepen the depressions formed by this action, though ice erosion would not in this case be the prime cause for the basin.

These [rock-basins] seem to be depressions caused rather by preglacial decay than by glacial erosion. They are often so small and bounded by walls so angular that origin by ice scouring seems impossible.[1]

The valley lakes.—The line, marked "AB" on the map, indicates the position of one of the largest valleys on the peninsula, with seaward termination on the east and west sides, and is from three and a half to four miles in length. Fig. 3 shows cross-sections, with reference to sea level, of the east and west ends of this valley. "A" was sketched at a point in the valley 165 feet above sea level, while "B" is only 15 feet above. Neither of these has been platted to any scale. A glance at the two is sufficient to note the contrast in outline of the two ends of the valley. The south end, A, is filled in on all sides to an unknown depth with perfectly angular blocks of large dimensions. This difference in valley width for the two ends is due, probably, in a great measure, to preglacial conditions. It is more than likely, that the preglacial divide was located near the south end of the valley, with its western end farther down stream, and therefore wider. The west end of the valley is fully three fourths of a mile wide, with inclosing walls rising 1000 feet and more above the bottom, sloping at a steep angle—less than 45°.

The valley further holds the largest lakes distributed along any one of the valley bottoms (see Fig. 2). Careful soundings were made of all the lakes located in this valley, and two showed their bottoms to be considerably below sea level. The position in the lakes where soundings were taken are marked on Fig. 2. After the sounding data were obtained, several possibilities naturally suggested themselves to account for this condition, in the lakes. A close examination of all the conditions, however, resulted in the elimination of all save one of the possibilities. Stream erosion with subsequent depression is eliminated on the ground of extreme irregularity of valley bottom. On the north and near the west end of the valley, the attitude of the strata is

[1] *Ibid.*, Bull. Geol. Soc. Amer. 1897, Vol. VIII, p. 255.

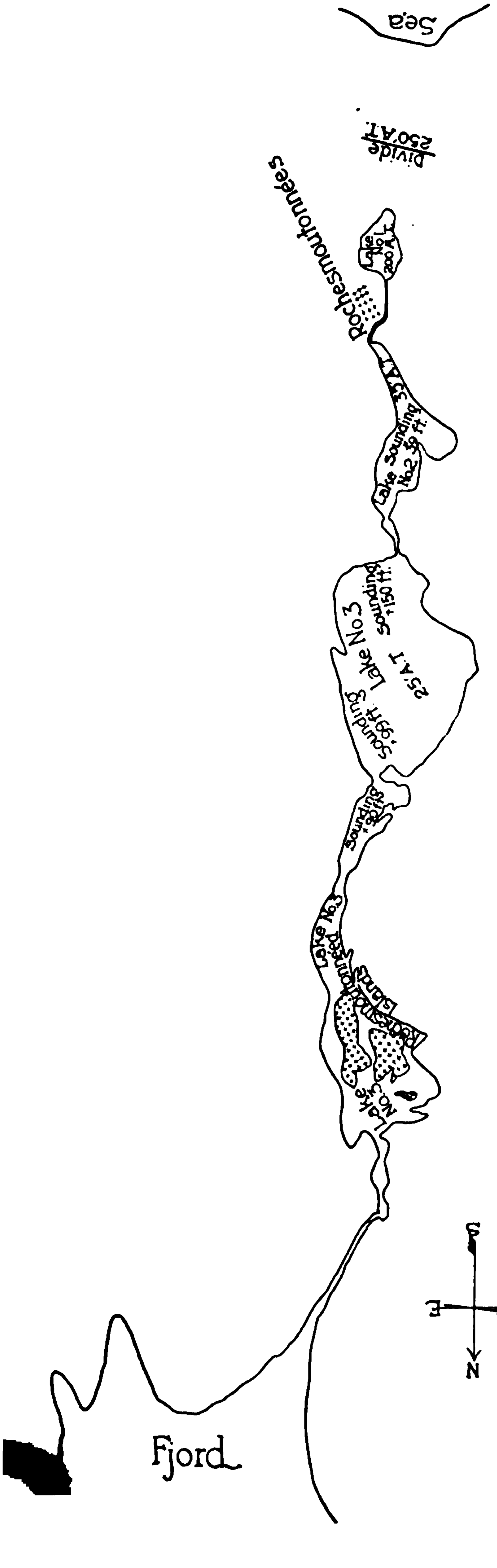


FIG. 2

Fig. 3. Cross-section of valley 'AB'.
A = E. end.
B = W. end.

of an overturned fold, whose axis is at right angles to that he valley. The position of the strata proved that at no t could the valley owe its origin to folding. Rock structure position were also opposed to origin by differential weather- The tracing of the same and equivalent strata on the two s of the valley would preclude faulting. Damming by depo- n of morainic material is untenable, since no moraines of extent occupy any portion of the valley.

The only other possibility to account for these lakes is that '*ice erosion*." A brief description of the lakes in this series, the closely associated glacial phenomena, will best show the ence for their glacial origin.

The first lake is the only one of this series with bottom above level. It is located 60 feet below the valley divide and 165 above the surface of the middle lake. It is more or less er-shaped in outline, and is, with the exception of the east , entirely inclosed between highly polished and striated tonnée forms.

he middle lake, marked lake No. 2 of Fig. 2, lies imme- ely against the high, precipitous south wall of the valley, inclosed entirely by moutonnée forms on its north, south, west sides. It is entirely surrounded by rock in place with ottom 39 feet below sea level. The moutonnée forms on north side of the valley are highly polished and planed, with ial grooves and striae greatly intensified, reaching from the 's surface up to an elevation of 100 feet. These are coinci- : with the trend of the valley.

The space between the middle lake and lake No. 3 of Fig. occupied by moutonnée forms of well-rounded outline and it elevation. Lake No. 2 drains into lake No. 3 through a : channel some 50 yards across and about 100 yards long, ed between the close-lying moutonnée hills.

The lake occupying the west end of the valley lies, for most ts length, immediately against the high, precipitous north . It is something over a mile in length, very narrow, and e irregular in outline, closely resembling a stream. It is

15 feet above sea level, and in its deepest part—near its head—is 150 feet below sea level. Perfectly developed glacial grooves and striae, with direction coincident with the axis of the valley, extend for quite a distance along the south border of the lake. The outlet channel is cut into solid rock, and averages from four to five feet in depth, with a U-shaped cross-section. The overflow passes over a low point in the divide between the lake and fjord on the southwest side of the valley. The divide is highly glaciated, and stands 25 to 50 feet above the lake level. As can be seen from Fig. 3, the portion of lake near the outlet is dotted with moutonnées rising to a slight elevation above the waters and forming a group of small islands in the lake. Bowlders of varying dimensions are found poised in various positions over the tops of nearly all the largest roches moutonnées in this valley. It will be further observed that the valley axis, AB of map, is approximately coincident with a westward advance in the general glacial movement over the peninsula. Further, that the largest and deepest water bodies are located in the northwestern portion of the peninsula, which portion is shown in a subsequent part of this paper to have been subjected to a period of more or less intense local glaciation. On the high hilltops forming the southwestern limits of the valley are found remnants of once larger local glaciers.

As a class, the valley lakes observed on the peninsula, range in size from something over a mile in length down to the smallest size basin. In outline, some were saucer-shaped—width and length about equal—but generally the length greatly exceeded the width, and when so found were invariably characterized by irregularity of outline. They varied from a few feet to 150 in depth, and in all cases their circumferences were marked by rock in place, proving them to be true *rock-basin* lakes. With but few exceptions they are prevailingly shallow and filled, more or less around their edges, with rock fragments derived from the valley sides, due to shattering by frost. Approximately eight to ten feet above summer water level and along the edges of parts of a few of the larger lakes were noted slender but perfectly formed

beaches. These may represent storm levels, or they may be the result of climatic changes. While the valleys probably cannot in all cases be ascribed to the same cause, the lakes associated with the valleys are, apparently, the result of differential ice erosion, and are true rock-basins, since they are walled in by rock *in situ* on all sides.

Dust wells and pools on the ice-surface.—The marginal surface area of the glacier ice was found dotted with numerous circular holes, varying from a quarter of an inch to several feet in diameter, and averaging probably several feet in depth. These were filled nearly to their tops with water, and their bottoms were invariably covered with a thick layer of dust. Professor Barton[1] has described the same condition to the south of this locality in the Umanak district, where he states, that the pits are confined to a marginal zone of about one mile in width, beyond which, and towards the interior, the ice surface becomes comparatively smooth. Professor Chamberlin[2] has observed the same conditions farther north along the west coast, and has fully discussed their origin in a previous number of this JOURNAL.

Other larger pools were seen. Professor Tarr[3] noted an especially large one, occupying a depression in the ice, of about one quarter of a mile in length in the direction of its longest axis, very shallow in depth, and revealing clear smooth ice, with no sediment over its bottom. No observation was made concerning its outlet, and Professor Tarr states that the pool probably represents a case of differential meeting.

Lakes due to other causes.— Along the ice margin, lakes were found, in places, formed by the usual ice marginal processes. A majority of these marginal lakes are due to a walling in of the numerous depressions of the extremely irregular surface of the peninsula, by the more or less steep ice-front on one side, and the slopes of the depressions of the land on the other. Each of

[1] Op cit., p. 216.

[2] JOUR. GEOL., Glacial Studies — Greenland, IV, Vol. III, 1895, p. 215.

[3] Communicated by letter to the writer.

these was fed by a marginal stream flowing along the ice front, which was, in turn, made up from the numerous smaller streams flowing off of the ice at its front. In some instances the lakes had been recently drained revealing heavy and conspicuous silt deposits, which necessarily were irregular in position, as is characteristic of marginal lakes. Some were found draining through tunnel outlets in and under the ice.

Morainal formed lakes, both by means of the masses ponding back the waters, and as kettles occupying the depressions in the morainal accumulations, were not uncommon.

Lakes noted at other points.—Rock inclosed bodies of water similar to those on the upper Nugsuak were noted at the following points: Turnavik Island, off the middle coast of Labrador; Big Savage Island, Hudson Strait; Icy Cove, the extreme southern coast of Meta Incognita; Niantilik, Cumberland Sound; and at several places along the Greenland coast to the south of the Upper Nugsuak peninsula. So far as observation extended their origin and development have been essentially the same.

At Niantilik a large number of typical rock-basins, resembling in every respect the Nugsuak lakes, were observed. Where studied, these were found developed in true strike valleys, and in case of the larger ones, roches moutonnées islands of slight elevation and formed by the hard layers of steeply tilted gniess were found. The character of these lakes left no doubt as to their being true rock-basins formed in part by ice erosion. Their entire circumferences were in many cases encircled by rock in place.

THE VALLEYS

No grouping of the valleys according to direction could be effected, since they were found trending with all points of the compass. An apparent series of major valleys were observed, cutting the peninsula in a direction varying from an almost east and west course to one at nearly right angles to this, which invariably had a seaward termination.

In a very general way, the larger valleys are best described as being very deep and broad, somewhat U-shaped in outline.

There are wide variations, however, from the steep sided and precipitous profile to that of considerably gentler slope. Frost action has wrought widespread results on the original glacial outlines of this form, resulting generally in a modification tending toward a less precipitous outline.

It has already been stated that numerous dikes of a basic eruptive rock, probably diabase, are found cutting the gneiss in an approximately vertical attitude. The basic dike rock of the peninsula has yielded more readily to the attack of the atmospheric agencies than the inclosing gneiss. Subsequent ice advance removed most of the residual decay, resulting in some instances, in the ice eroding considerably below the line of actual decay, determining thereby one set of the major valleys. The U-shaped outline is especially applicable to this type of valley.

Similar conditions apparently prevailed at Turnavik, Labrador, as on the Nugsuak. The rock is a coarse porphyritic gneiss cut by dikes of a basic eruptive, many of which have been eroded to a depth of some 20 to 25 feet by the ice, and in some of which residual decay was still to be seen, indicating a greater preglacial decay of the dike than country rock.

In the Umanak district of North Greenland, Professor Barton,[1] observed that the dikes of eruptive rock had not been eroded below the level of the inclosing gneiss, but instead, they were found, in some instances, standing "out in relief above the gneiss."

No petrographic study has been made of the rocks in the localities mentioned above, hence it would not be safe to say whether the difference could be accounted for on lithologic grounds, or whether it is due to a difference in glacial conditions.

A second type of valley, but of minor importance, on account of slight development, was noted; the origin of which was traceable to the etching out of the softer rock layers in the highly tilted strata by differential atmospheric weathering, and can therefore be classed as strike valleys.

Subsequent to the period of widespread general glaciation,

[1] BARTON, GEO. H., Technology Quarterly, 1897, 10, 236, 237.

the northern ends of the valleys have undergone considerable modification from a period of local glaciation, which is now confined to the northern side of the peninsula, and in its last declining stage Owing to the work of local glaciation, more or less contrast is observed in the topography of the opposite ends of the approximate northwest-southeast trending valleys (see Fig. 3). Glacial filling, principally bowlders with some till; abundance of typically developed roches moutonnées, glacial grooves, striae, planing and polishing, conspicuously characterize all of the major valleys.

A large number of the major valleys were associated with dikes of basic rock. So far as studies were extended, the mass of fact pointed to the conclusion, that this type of valley was due to differential preglacial decay with subsequent ice erosion. The entire set of major valleys, everywhere viewed on the peninsula, are distinctly preglacial; and while their origin was not apparent in every case, they have all suffered considerable subsequent modification from ice erosion.

A parallel is probably found in Canada, where Dr. Robt. Bell[1] has observed greenstone dikes protruded into granites. The dikes have subsequently been worn out and at present form valleys occupied by lakes and streams.

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[1] BELL, DR. ROBT., Bull. Geol. Soc. Amer. 1894, V, 364.

.N ATTEMPT TO FRAME A WORKING HYPOTHESIS OF THE CAUSE OF GLACIAL PERIODS ON AN ATMOSPHERIC BASIS

(Continued)

SPECIAL APPLICATION OF THE HYPOTHESIS TO THE KNOWN GLACIAL PERIODS

IT now remains to specifically apply the hypothesis to the :cognized glacial periods. At present only those at the close f the Paleozoic and Cenozoic eras are sufficiently determined to :quire discussion.

The mapping of the Pleistocene glacial deposits is sufficiently omplete to show their great features, and reveals a strong evelopment in the northern hemisphere, and at the same time quite peculiar localization. The analysis of the deposits has rogressed far enough to show that the glacial period was iarked by pronounced oscillations of both the major and the iinor kind. Interglacial epochs of a declared character may be ssumed to be fairly demonstrated, while the glacial epochs iemselves were attended by rhythmical stages of progress, as iost pointedly brought out by recent detailed field work in the Iississippi and St. Lawrence valleys, notably that of Mr. Leve-:tt and of Mr. Taylor. These rhythmical features are made the ıbject of a special discussion by Mr. Taylor in a paper entitled Moraines of Recession and their Significance in Glacial heory."[1]

To be really applicable to Pleistocene glaciation a working ypothesis must therefore not only postulate agencies capable f producing a glaciation covering the American plains down to

[1] JOUR. GEOL., Vol. V., No. 5, 1897, pp. 421–465. See also "The Great Ice-ams of Lakes Maumee, Whittlesey, and Warren," American Geologist, Vol. XIV, No. 1, July 1899, pp. 6–38, and the review of this paper by MR. GILBERT in e last number of the JOUR. GEOL.

37° north latitude, and mantling also the plains of middle Europe and high altitudes quite generally, but it must assign agencies for the oscillations which attended it.

General cause.—The atmospheric hypothesis finds a general cause for the Pleistocene glaciation in that notable extension and elevation of the land which reached a climax near the close of the Pliocene period. It is not, however, through its direct topographic influence that this was accomplished, though this may have been incidentally tributary, but through its effects on the constitution of the atmosphere. The recently named Ozarkian or Sierrian period embraces the specially effective stage of this great land area, and it is with much pleasure that I support the emphasis laid upon the significance of this period by Professor Le Conte in his paper in the last number of the JOURNAL,[1] though I interpret that significance in different terms. The wide extent and high elevation of the land at that time are so strongly set forth by Dr. Le Conte as to leave no need for additional emphasis here.

A rude estimate of the land area in Middle Tertiary times, when the climate was mild far to the north, gives about 44 million square miles. A similar estimate for the Ozarkian or Sierrian period gives about 65 million square miles, while the received estimate of present land is about 54 million square miles. Taking the Middle Tertiary area as a basis of comparison, the land was increased in the Ozarkian period about 47 per cent., and afterwards fell off to the present area, which is 23 per cent. greater than that of the mid-Tertiary. It is probably conservative to estimate that the average elevation of the Ozarkian land was at least two or three times, perhaps three or four times, as great as that of the mid-Tertiary. Combined in the light of the suggestions previously made regarding elevation, these indicate a very great change in the effective contact of the atmosphere with the earth. If we measure the actual contact by the surfaces of the grains, pores, fissures, and minute crevices with which the air and the atmospheric waters come in contact

[1] Pp. 525–544.

—and this is the true contact area—the increase will appear impressive.

As in other cases, there was here also a self-accelerating action. As land was elevated, its underground water level was at first carried up measurably with it and lay near the surface. Trench-cutting accompanied it, to be sure, but at a slower rate. As the declivity increased the cutting and transportive power of the drainage increased, and as the dissection of the land proceeded, the water level was lowered and the effective zone of atmospheric contact augmented. The very process of degradaion, up to a certain stage, increased the facilities for the chemical action of the atmosphere. In general it may be observed that degradation reacts upon itself favorably for a time. The cutting of certain of the western plains into "bad lands" and the gullying of the cultivated fields in certain parts of the southern states are striking examples of current self-accelerating processes of the more mechanical sort.

Concurrent with this increase of the atmospheric contact-area on land there was a reduction of sea surface, the habitat of lime-secreting life, and, *nota bene*, an almost complete obliteration of the epicontinental seas and sea-shelves which were the parts of the sea bottom that were by far the most prolific in carbonic-acid-freeing marine life. Shallow-water marine life must have been very generally driven down on the abysmal slopes and on to such limited deeper shelves as may have been brought within reach by the lowering of the seas. The consequent lessening in the rate of freeing of carbon dioxide is assumed to have been great, and this coöperated with the accelerated consumption on the land to hasten the depletion of the atmosphere.

Besides this, when any appreciable reduction of temperature followed these coöperating agencies, it tended of itself to check the lime-secreting life of the ocean, and at the same time to give the oceanic waters greater absorptive power and less dissociative activity, thus calling into operation a group of secondary agencies which intensified the effects of the primary agencies.

phases. The salient effect of this, reasoning on general principles, must be to push results to an extreme from which reaction is inevitable. Let us consider this in detail. It is thought that there were three dominant agencies concerned in this, modified by several subsidiary ones.

1. A necessary consequence of the accelerated rate of transmission of carbon dioxide to the sea, combined with a slackened rate of release in the sea, was an accumulation of oceanic carbon dioxide. The primary form of this was an increase of the carbonates.

2. The cooling of the sea waters which attended the process reduced the dissociation, and hence the carbonates were more nearly full bicarbonates than before. *There were, therefore, not only more carbonates, measured by the bases, but they carried more carbon dioxide in proportion to the bases.*

3. With the growth of the snow-fields attendant on the progress of glaciation, there was an increase of reflection of the sun's radiation and a reduction of its absorption. Computation shows that the albedo is an important factor.

Subsidiary to these there were the following:

4. There was an increase in the absorption of carbonic acid in the ocean, resulting from the lowering of the temperature. This, however, was offset by the declining partial pressure of the carbon dioxide in the air, and, as the two seem to be of the same order of magnitude, they may be set aside for the present.

5. With increasing cold there was a less rapid decay of organic matter and a less complete release of carbon dioxide. Over against this, however, there was a reduction in the amount of carbon locked up in living organic matter. It is difficult to form a trustworthy estimate of either, but it may be provisionally assumed that they belong to the same order of magnitude and may be set aside together. At any rate, any residual difference would not apparently be a notable factor.

6. The majority of chemical authorities state that the solubility of calcium carbonate in water saturated with carbonic acid increases with a lowering of temperature through ordinary

ranges. Unfortunately there is not complete unanimity on this point. But, if this be true, as the temperature fell the solvent action of the carbonic acid of the land waters upon the limestone was increased. Over against this was a probable reduction of the action of organic acids. Probably the decomposition of the silicates went on at a lower rate, but, as it was much less than one fifth of the whole action, its reduced rate is not very material here.

As the carbonic acid of the air was diminished, its action on the land surface declined—though not at a proportional rate—but long before it could offset the enlargement of the contact area aided by the sea action, glaciation would be far advanced, if the previous estimates hold good.

Setting aside, as being measurably balanced, or as being of minor or uncertain value, all but the first three items, which are clearly factors of great potency, we find at first a strong disposition toward the acceleration of the depleting process.

But this, although a pronounced influence in the early stages of refrigeration, could not continue indefinitely, for the process involved the conditions of its own arrest.

The arrest of the depletion and the inauguration of the reaction.—With the development of glaciation, the agencies that tended to counteract atmospheric depletion received a powerful ally in the ice-sheet itself. The spread of the ice over the surface prevented further effective weathering of the area so covered and correspondingly arrested atmospheric depletion. The total area covered by glaciation at its maximum was probably not far from 8 million square miles, or nearly 15 per cent. of the land surface.

Besides this, the area outside of that actually covered by the ice-sheets was probably affected by prolonged freezing during the winter stages, and was perhaps to some extent permanently frozen beneath the surface, and this arrested solvent and chemical activity. If the modest figure of 5 per cent. be assigned for this supplementary effect, 20 per cent. of the functional area would be withdrawn from action. Whether this numerical estimate be correct or not, it may be assumed that if a given amount

of withdrawal, combined with associated agencies, were not sufficient to arrest the progress of glaciation, the glaciation would have continued to extend itself until the point of balance was reached. It is, perhaps, not too much to assume that the extension of glaciation and its concurrent agencies mark in themselves the measure of preponderance of the depleting agencies at the stage when glaciation began. That is to say, after the depleting agencies had brought the air's carbonic content down to the point at which the glacial centers were inaugurated, these agencies were still preponderant over the repleting agencies to some such extent as 20 per cent., more or less.

While it does not seem necessary to our general purposes to consider the associated agencies of arrest, if these views be correct, they possess an interest of their own, and may be mentioned briefly.

With little doubt the lowering of the temperature lessened the rate of decomposition of the silicates, though frost action aided in disaggregating them mechanically and in thus increasing the atmospheric contact. On the other hand, while the authorities are not altogether agreed, the weight of the latest opinion supports the view that the limestones would be dissolved by cold water saturated with carbon dioxide faster than by warm water, other things being equal. The cold waters would quite certainly contain more absorbed carbon dioxide than warm ones. Probably other things were not equal, for the vegetable action and the organic acids probably lent less and less aid as the temperature fell. It is not clear what the balance of these influences combined would be. Whichever way it leaned, it does not seem to have been of decisive moment.

As previously remarked, the progressive removal of carbon dioxide from the air reduced the amount of its action, but not proportionately. While this lessened the depleting action it does not seem to have reached decisive moment, at least not until a late stage in the process of depletion.

Meanwhile, in the ocean, conditions favoring reaction were

gathering force as the result of the processes in action there. The ocean was accumulating carbonates and augmenting their degree of bicarbonation with the increase of cold. Now it is obvious that if the loading of the ocean with carbonates were to proceed to the point of saturation, inorganic processes of precipitation and dissociation would come into play to an extent that must necessarily balance all further accessions of material. It does not appear, however, that there is enough, or even nearly enough, carbon dioxide in the air to bring about a condition of full saturation of the ocean with bicarbonates, even if it were all to take that form, and were to be conveyed completely to the sea. But the movement toward saturation should increase in some degree, probably small, the efficiency of inorganic agencies tending toward precipitation, although it could become notably effective only after prolonged accumulation.

The concentration of carbonates in the ocean was somewhat aided by the removal of water required to form the great ice-sheets. On a rather large estimate of the mass of the ice-sheets, this extraction might possibly reach 5 per cent. of the volume of the ocean.

There would probably be a progressive evolution of lime-secreting life adapted to the cooled waters, and this would increase the rate of carbonic release and contribute to a reversal of action.

None of these subsidiary agencies, nor all combined, seem to have been controlling factors.

It is notable that some of these subsidiary agencies, on both sides, are final in themselves and quite without retroactive possibilities. When once their work was done there was no resilience. It was quite otherwise with the ice mantling and the ocean loading. Far from being final, these contained in themselves the potentialities of reaction and gave vigor to the reaction when it took place.

Agencies that precipitated reaction.—When once the reactive agencies had reversed the relative rates of enrichment and

depletion and there began to be an increase of carbon dioxide in the air, the following influences would coöperate to hasten and intensify the reactive movement.

1. The dissociation of the second equivalent of carbonic acid associated with the carbonates of the ocean would be increased, and as the temperature rose from the diffusion of the freed carbon dioxide into the air this would be still further augmented by its own reactive effects. This is one of those interesting agencies whose effects at once become causes of further like effects.

2. The increased warmth would call forth more lime-secreting life in the ocean, and thus also hasten the freeing of carbon dioxide, and this again would react favorably on itself.

3. The increase of water from melting ice would somewhat extend the shallow-water zone and favor lime-secreting life. If the land were depressed by the load of ice, as some suppose, this would increase the sea area and favor lime-secreting life. With this may be associated the falling of the water level in the high latitudes (to which it had been drawn by the gravitation of the accumulated ice mass) and a corresponding rise of the water level in lower latitudes. Since the lower-latitude life is more abundant than the high-latitude life, and more effective in extracting lime, the shift would involve a gain in lime-secreting potency.

4. The increased decay of organic matter attendant on the warmer temperature would develop carbon dioxide; but over and against this must be set the increased carbon locked up in the augmented living matter. These, as before, are set aside, as perhaps mutually offsetting each other.

5. The increase of temperature arising from the preceding causes would increase the water vapor in the air and thereby add to the thermal capacity of the atmosphere, and this would react favorably upon itself and upon the other agencies favored by high temperature.

Thus the reaction once started would be self-augmenting,

until the fundamental conditions were changed or the reaction was checked by its own ulterior consequences. The sequences may be easily followed. The carbonates of the sea, which had been augmented during the epoch of glaciation were now diminished and limestone was more actively deposited. The ocean, previously fattened in carbonates now became lean. So also the carbonates themselves, that before were quite plump bicarbonates, now became degraded to a mixture of normal and acid carbonates. In short, the ocean holds less free and feebly-combined carbon dioxide and the air holds relatively more. As the ocean is now estimated to contain from eighteen to twenty-five equivalents of atmospheric carbonic acid in the free and feebly-combined states, a moderate fluctuation in its content would cover the full range of atmospheric variation required to produce the climates under discussion, according to Arrhenius. On the supposition that the glacial epoch was produced by a reduction of the carbonic content of the atmosphere to one half the present amount. it would only be necessary for the ocean to release 2 or 3 per cent. of its releasable carbon dioxide to restore the atmosphere to the present condition. If the ocean gave up 4 or 5 per cent. of its releaseable carbon dioxide the climate would be notably milder and more equable than the present. Assuming the correctness of Dr. Arrhenius' conclusions, it would seem from these considerations that there is nothing forced or violent in the supposition that an effective interglacial epoch might be brought about by the reactive agencies indicated.

Recrudescence of glaciation.—If the land area of the globe as a whole remained large and high notwithstanding such local depressions as have been attributed to the weight of the ice and the effects of low temperature; or, more precisely, if the atmospheric contact area remained large, the conditions for a renewal of glaciation would again prevail because the renewal of warm temperature, the enrichment of the atmosphere, and the depletion of the ocean would restore the original action. So soon as the ice had retreated from the land, the weathering of the

uncovered area would be renewed. This, of course, would begin so soon as the retreat began, and increase in a corresponding measure; but it is a slow process, while the reactions of the ocean are relatively rapid —indeed they should keep close pace with the rise of temperature which they induce. There should be no appreciable lag. After the retreat of the ice a new surficial factor would come into play, the sheet of drift spread over the surface. In so far as this consisted of undecomposable matter blanketing decomposable matter, it would interfere with the progress of decomposition, but in so far as it consisted of limestones and silicates ground to a flour and exposed to the atmosphere, it would facilitate chemical action and expedite a second depletion of the atmosphere and through it a second term of glaciation. Aside from the effects of this mantle of drift and such changes of topography as might have occurred, the conditions for the renewal of glaciation would be, so far as I see, as effective as they were at the outset. Assuming that they were equal to the preceding, a second glaciation equal to the first is to be postulated, and a corresponding reaction at length, as in the previous case, due to like agencies. Thus a series of glaciations and deglaciations should follow each other until the general causes lying back of glaciation had disappeared.

In so far as the land, on the whole, settled back toward sea level or was worn away, or, by any other agency, lost its degree of effective exposure to the atmospheric action, in so far the conditions of glaciation would disappear. Pursuing the normal history which follows a period of great land elevation, it is to be presumed that there would be a gradual reduction of the land surface and land elevation, and that hence the conditions productive of glaciation would gradually pass away. On such an assumption it is presumed that the recurrent glacial advances and retreats would become more and more feeble until the series vanished. Nominally, then, the glacial and interglacial epochs should form a rhythmical series declining from large oscillations at the maximum to lesser and lesser oscillations as the series

disappeared. This seems to correspond with the observed oscillation of glaciation in both Europe and America.[1]

INTERCURRENT AGENCIES

Without question the normal series of glacial oscillations just postulated would be subject to intercurrent influences which would be liable to disturb, perhaps quite seriously, its regularity and symmetry.

1. Any notable movement in the land which affected the sum total of the atmospheric contact area would disturb the symmetry of the series.

2. Any notable change in the original supply of carbonic acid through volcanic action or other agency would produce obvious modifications. The deformation of the body of the earth out of which the conditions of glaciation are assumed to have sprung would doubtless be favorable to volcanic action, and if this reached a degree of intensity sufficient to add appreciably to the carbon dioxide of the atmosphere, it would radically affect the ongoing of the process. That there was extensive vulcanism nearly or quite concurrent with glacial action has been urged by some geologists; indeed, glaciation has even been attributed to volcanic action.

3. The precession of the equinoxes has been regarded by many thoughtful students of glaciation as an influential agency. If affective, it would superpose a rhythm of its own upon the rhythm postulated by this atmospheric hypothesis. For specific illustration the extensive series of moraines which marked the later stages of the Wisconsin epoch of glaciation are referred by Taylor to precessional influence, while the Wisconsin glaciation itself would, under the atmospheric hypothesis, be referable to atmospheric depletion. The most serious question which here arises is the compatability of the prolonged period implied by Taylor's interpretation with the rate of reaction implied by the

[1] The Classification of European Glacial Deposits, JOUR. GEOL., Vol. III, No. 3, pp. 241–269, JAMES GEIKIE; The Classification of American Glacial Deposits, *ibid.*, pp. 270–277, T. C. CHAMBERLIN; editorial, *ibid.*, Vol. IV, No. 7, October–November 1896, pp. 873–876.

:mospheric hypothesis.[1] This will be more evident as we touch n the time rates.

4. The change in the eccentricity of the earth's orbit which roll has made the foundation of his beautiful hypothesis of laciation, if not found competent to produce general glaciation self, might still be effective in producing climatic changes of ss degree, and might superpose important modifications upon ie series postulated by the atmospheric hypothesis. It may e remarked in passing, however, that the computed variations f eccentricity of distant periods of the past do not rest on so rm a mathematical basis as is currently supposed.

It is obvious that these and other possible agencies might ork concurrently with the atmospheric influences, or antago- istic to them, in either case distorting and masking the normal iythmical expression which a purely atmospheric series would ssume.

DO THE TIME RATES FALL WITHIN WORKABLE LIMITS?

The working capabilities of a glacial hypothesis are some- hat severely conditioned by its time factors. It must not only resent a satisfactory correlation between the time of occurrence f glaciation and that of the assigned cause, but the rhythmical ction of the cause must be consonant with the rhythmical history f glaciation. That the Pleistocene glaciation followed the)zarkian or Sierrian stage of elevation at an appreciable dis- ınce, I hold to be demonstrated by the relations of the glacial eposits to the eroded topography of that period. On the other and, there is no evidence of a prolonged interval, geologically peaking. The atmospheric hypothesis demands that the accel- rated erosion due to elevation (or rather to the dissection that ollowed elevation) should have continued long enough to emove about three times the present atmospheric content of car- on dioxide before glaciation could begin, following Arrhenius' omputations. This removal could only be accomplished by the *xcess* of consumption of carbon dioxide over supply and there is

[1] See GILBERT's review in last number of this JOURNAL, p. 621.

reason to believe that the rate of supply from the interior was greater than the average on account of crustal disruption and volcanic action. There seems, therefore, little ground to think that the glaciation should have followed closer after the elevation than it seems to have done. It would seem rather that the hypothesis was happy in this time relation at least.

With most geologists, I doubt not, the chief question will be whether the postulated agencies could cause the glacial oscillations, involving the removal and reproduction of the ice, in large part or in whole, as rapidly as the field evidence requires. Present measures of glacial rates and times are quite uncertain but not indefinitely so. Some rude approach to their value may be attained. Recently expressed opinions regarding the time since the last ice retired from the site of Niagara River, and inaugurated the erosion of its gorge, lie between 7000 and 33,000 years, which we may average at 20,000 years. I place no special confidence in this figure, but it is rudely representative of the average order of magnitude of expressed opinion. This represents only a part of the time since the beginning of the deglaciation that removed the Wisconsin ice-sheet. According to Taylor's views it would be only a very small part. I doubt if any careful geomorphic geologist familiar with all the phenomena involved would seriously consider an estimate that made it much more than one half at the most; so that it would apparently not be straining the evidence to take 40,000 years as a rude measure of the time since the beginning of the retreat from the outermost moraine of the Wisconsin stage. However, this may probably be cut in half and halved again without over-straining the possibilities of the hypothesis.

This is the time of retreat. An interglacial epoch involves not only the time of retreat, but the time of interglacial mildness and the time of re-advance. The best specific data now available in America for estimating these elements are undoubtedly those afforded by the excavations about Toronto which have

een so fruitfully cultivated by Hinde, Coleman, and others.[1] 1) The time occupied in the ice retreat is there almost without ecord. (2) The duration of the mild climate is recorded in hirty-five feet of clays and sands. It is also implied in the time ecessary for the migration of the Paw Paw, Osage Orange and ther trees from more southerly regions to this rather northern ocality, and also for the migration of the clams and other molluscs from the Mississippi waters to this rather distant region. Both of these migrations were probably rather slow processes. 3) The initiation of the returning cold is recorded in 150 feet f fine stratified peaty clays and sands. (4) Following this here was an unknown period occupied in the transition from the onditions of deposition, during which the preceding series had een formed, to the conditions of effective erosion which folowed. To suppose that this transition was due to the removal f an ice-dam that had lingered in the lower St. Lawrence seems uite untenable for a long, mild period and a long, cool, but not lacial, period had intervened. It was probably due to the cuting down of the drainage outlet, or to a surface movement, or he two combined, and hence probably occupied an appreciable ime. (5) There then followed a period of erosion comparable o that since the last ice invasion. Succeeding this came the e-invasion of the ice-sheet.[2] These data seem to fairly imply hat the interglacial epoch represented at Toronto was several imes as long as the postglacial epoch.

While nowhere else has so complete a record been found, many estimates of the differences of erosion of the several till heets in the Mississippi valley, where the formations are well eployed and happily suited to such studies, have been made

[1] GEORGE JENNINGS HINDE: Glacial and Inter-Glacial Stages of Scarborough Heights. Can. Jour. 1878, p. 388 *et seq.*

A. P. COLEMAN: Am. Geol., Vol. XIII., February 1894, pp. 85–95. Ditto. JOUR. GEOL., Vol. III., No. 6, 1895, pp. 622–645.

[2] Canadian Pleistocene Flora and Fauna: Report of the Committee consisting f Sir J. W. Dawson (chairman), Professor D. P. Penhallow, Dr. H. M. Ami, Mr. G. V. Lamplugh and Professor A. P. Coleman (secretary), appointed to further investiate the flora and fauna of the Pleistocene beds in Canada.

by experienced glacialists, and their concurrent judgment is that the least of the notable interglacial intervals was at least two or three times as great as the postglacial interval. It would not be exceeding current judgment, therefore, to assign from 80,000 to 120,000 years as the duration of a typical interglacial epoch.

But in the interest of conservatism let the postglacial interval be taken at 10,000 years and the interglacial at 20,000 or 30,000 years. This seems to me excessively conservative. If the assigned agencies can affect a reënrichment of the atmosphere in carbon dioxide to an amount somewhat exceeding the present content and then again a depletion of one half within 20,000 or 30,000 years, the hypothesis will not be excluded by time limitations.

We have the following pertinent data based in part on Reade's[1] estimates of the present rate of removal of carbonates:

Total mass of the atmosphere - - - - - -	5×10^{15} tons
Mass of atmospheric CO_2 (reckoned by weight at .0006) -	3×10^{12} tons
Total mass of CO_2 taken annually from the atmosphere -	162×10^7 tons
Mass of CO_2 consumed annually in original carbonation (reckoned by area at 20 per cent. of the land) - -	27×10^7 tons
If reduced one half on account of the slower rate of decomposition of crystallines it will be 13.5×10^7 tons, in which case the other half is to be added to the following item, if Reade's estimates are correct.)	
Mass of CO_2 consumed annually in forming bicarbonates -	135×10^7 tons
Time required at this rate to consume total atmospheric CO_2, assuming no return - - - - - - -	1852 years
Time required at this rate, without return, to consume one half atmospheric CO_2 (the reduction requisite for glaciation.) - - - - - - - - - -	926 years
Time required to consume half the "free" and "loose" CO_2 of the ocean (estimated at 18 times that of the atmosphere) without return - - - - - -	16,668 years
Time required to consume half the CO_2 of the atmosphere and the ocean combined, without return - -	17,594 years

The last items which involve the reduction of the carbon dioxide in the ocean as well as in the atmosphere are not really

[1] Loc cit. on p. 569.

pertinent to the discussion, if the foregoing doctrine relative to the mode of action of the ocean during a glacial period is correct, for it is there maintained that the ocean does not give up its carbonic acid with increasing depletion of the atmosphere, but, on the contrary, increases its content. They have some interest, however, in connection with it and with other phases of the atmospheric hypothesis which the reader may possibly wish to consider. They also have some pertinency to the discussion of Paleozoic glaciation, to be taken up presently.

We are here concerned especially with the rate at which atmospheric carbonic acid may be consumed to the amount of one half the total content. For convenience, no account has been taken of the return of carbonic acid from the ocean or through organic action. We reach the rather startling result that if there were no return, the decomposing and solvent action on the present contact area would consume one half of the atmospheric carbon dioxide in less than 1000 years. This result, based on Reade's estimate, may be checked by independent computation on a more familiar basis and by different modes of computation. For example, by assuming the average rate of degradation of the land surface to be one foot in 5000 years, and that the carbonates constitute 15 per cent. of the material removed, one half of the carbonic acid of the atmosphere would be consumed in 1248 years, if there were no return; or in 1000 years if the degradation was one foot in 4000 years.

The actual depletion must, of course, depend upon the excess of this rate of removal over the rate of return. I have already endeavored to show that there was a very large fluctuation in the conditions that determined the relative rates of consumption and return, notably that the land of the Ozarkian time was more than 20 per cent. greater in area than the present land, and that its elevation was probably 100 per cent. or 200 per cent. greater at the maximum stage of protrusion. And this was correlated with coöperating conditions in the ocean. Both of these estimates, however, must be considerably reduced to give a safe measure of the area which was operative at the time of the

inter-glacial epochs, or at least some of them, for there is abundant evidence that the land was not then so greatly elevated as in the Ozarkian or Sierrian period.

Instead, therefore, of combining 20 per cent. increase of land area with 100 per cent. increase of elevation, and these with the coöperating 20 per cent. reduction of sea area, the destruction of sea-shelves, and the restraining effects of lowering temperatures, as we are entitled to in bringing down the rich Tertiary atmosphere to the lean conditions of the glacial period, let us content ourselves with some modest fraction of these intensifying combinations. If we only assume that the agencies of depletion were superior to the agencies of return by the amount of 10 per cent., the depletion requisite to bring on a glacial epoch, starting with atmospheric conditions like those of the present, would be effected in less than 10,000 years. If, therefore, we over-generously allow as much time for deglaciation as for reglaciation, an interglacial epoch might not require the operation of the postulated agencies for more than 20,000 years, so far as they themselves are concerned. The development of the ice-sheet might take more time, but we have little or no data for estimating this. If 10,000 years additional is allowed for this the total remains at the modest figure of 30,000 years.

It would not seem to be pushing the data previously given to extremes to postulate a larger percentage of difference between depleting and repleting agencies than 10 per cent., which would make the requisite atmospheric depletion possible in a shorter period. It is probably not extravagant to assume that the difference might rise to 20 per cent., in which case the requisite time would be brought down to extremely modest limits. It is difficult to see how anyone who studiously considers the phenomena of the Toronto interglacial epoch could assign to it a duration less than is compatible with these agencies, as here interpreted. It would seem, therefore, that the hypothesis is not excluded from the working category by inadaptibility to the time rates of the phenomena which it seeks to elucidate.

There is not likely to be any serious question respecting the

time rates at the other extreme, that is, that the agencies necessarily act too rapidly to correspond to the phenomena. Of course, in the final adjudication of the hypothesis, it will be necessary to show that its time rates not only might correspond to the time rates of the phenomena, but that they did so, but this is a labor of the future, and is obviously dependent upon a very notable extension of precise knowledge, which it is the purpose of the hypothesis to aid in calling forth. It is sufficient here to show that reasonable postulates, based on a reasonable estimate of the phenomena, fall within compatible limits.

T. C. CHAMBERLIN.

(To be continued.)

Introduction of new names.—In the early days of petrography it was supposed that there existed rock types as definite as mineral types. Following this hypothesis, a rock found which was different from any rock before described was immediately given a new name. This went so far that an altered rock was given a family name, as in the case of *diabase*, an altered dolerite. After some years a scheme of nomenclature was worked out which was supposed to be approximately complete. For a time subsequently, when a rock was discovered having a somewhat different character from previously known rocks, it was referred with modifying mineralogical prefixes to some of the so-called types.

A few years ago another period of name-giving was inaugurated. During this period, which continues to the present time, petrographers have introduced numerous new, independent names, both for long-known and for newly-discovered varieties of rocks. Since 1890 more than fifty new names have been added to the nomenclature of the igneous rocks, a larger number than young petrographers were obliged to know the meaning of before 1890. The stage through which petrography is passing is somewhat similar to that through which at one time paleontology passed. One might almost think that petrographers were seeking to find varieties of rock slightly different from those before known in order to give them new names.

Method in giving new names.—The method of petrographers in proposing names, so far as any method is discoverable, is to give an independent name to each rock which is slightly different from any previous rock found, without reference to any definite plan of nomenclature. The greater number of the names are not proposed to designate varieties which are subordinate to previously recognized kinds of rocks, but are names coördinate with those before used. In petrography, a binomial nomenclature thus far has not been generally adopted, and therefore it has

not been possible to drop the new name and place the thing referred to under a larger division, as one may drop the specific name of a new fossil and speak only of the genus to which it belongs. Furthermore, the new names of petrography are in most cases unlike most of those in biology or in mineralogy, in that the things described and given names have no clearly distinguishable characteristics by which they may be recognized. As a result of this inherent vagueness, it is very difficult indeed, from the descriptions published, to obtain a clear conception of what is meant by many of the new petrographical names. Indeed, it may be doubted whether many professional petrographers, to say nothing of those who work in other lines of geology, have a definite conception of the meaning of many of the fifty or more names which have been proposed since 1890.

Principle underlying naming of rocks.—In giving numerous new names to rocks, while no principle is announced by the petrographers, the underlying assumption is the same as that which prevailed in the early days of petrography; that is, rocks may be divided into definite types, which are comparable to definite mineral or animal species. I do not for a moment suppose that petrographers who have introduced these new names would state that they believe this principle. I merely assert that many of the numerous names are justified only if the principle be true.

Responsibility of introducing new names.—The petrographer who introduces a new name for a rock assumes a responsibility which ought to be incurred only after the most careful consideration. Probably some of the new names which have been recently introduced were necessary to the progress of the science. That many of them were not, I venture to believe. One who introduces a new name without the best of reasons for so doing is hindering the advance of the science of petrography, as well as occasioning loss of time and great inconvenience to his fellow workers.

Statement of the problem.—All philosophical petrographers now understand that between all kinds of rocks there are gradations—from basic to acid, from coarsely granitic to glassy, from rich sodium

rocks to rich potassium rocks, from massive lavas to tuffaceous forms, from the freshest rocks to the most altered, from the oldest rocks to the newest, from the igneous to the aqueous rocks; between all of the various forms of the sedimentary rocks. Moreover, many of the important stages of these gradations have been noted. Still further, in one region the gradation from one kind of rock is in one direction, and in another region is in a different direction. For instance, here a granite grades into a diorite; there grades into a syenite.

What shall be the criteria for naming rocks?—These being the facts, the question arises, what is the most important consideration which shall determine whether or not a certain kind of rock shall be assigned a name. It appears to me clear that the most important consideration is *the relative abundance of the rocks.* We must have names for the common things. It is well known that certain of the multifarious kinds of rocks which have been named are more abundant than others. Probably the igneous rocks, which can be included under twenty names, comprise nine tenths or more of the mass of the igneous rocks. It follows that a philosophical method of rock nomenclature involves a knowledge of the relative abundance of the different kinds of rocks.

However, it is not meant to imply that abundance shall be the only consideration in the naming of rocks, but merely that it shall be a fundamental one. While abundance ought to be the first consideration, this idea must not be pushed to an extreme. All rocks which must be assigned names will not be found in equal abundance. Some rocks which do not have specific names assigned to them may be more abundant than some other rocks deserving of a name. For instance, olivine-gabbro may be more abundant than some of the leucite rocks to which names must be assigned. This but illustrates the well-known principle that great variations due to secondary factors shall have weight in proportion to their range, and that therefore they may have an important modifying influence upon the application of the primary considerations.

Influence of rock classification on naming of rocks.—The broad question of rock classification I do not intend here to discuss. However, it is necessary to mention some of the criteria which are recognized in the classification of rocks, since these are also factors in the naming of rocks. By most petrographers, chemical composition, mineral constituents, and rock textures and structures are controlling considerations; but by different petrographers these are placed in different orders of importance. By some petrographers the distinction between plutonic and volcanic rocks is given weight in classification. In making a classification of rocks it is necessary to consider to what extent the altered rocks shall be recognized, and whether such textural terms as porphyry and obsidian shall be used in naming rock species. Doubtless different petrographers would decide these points in various ways.

Now the above factors, which are controlling considerations in the classification of rocks, are of necessity secondary factors in the naming of rocks. If a new rock be found, which, in regard to these secondary factors, is so different from any previously known rocks that it cannot be grouped with any of them by the plan given below, it may be entitled to a new family name, even if not abundant.

But to return to the matter of abundance. After a system of classification shall have been worked out by a petrographer, he must decide what rocks shall have independent names. It is my contention that at this point abundance shall be recognized as having the place of first importance. Names are tools by which we avoid the circumlocutions of descriptions. Since, as already shown, there are everywhere gradations between rocks, not every phase of rock can have an independent name, else the number of names would be infinite. Since every rock phase cannot be assigned a name, what kinds shall be selected for such names? Manifestly those which occur most abundantly. For the common things, the common kinds of rocks, as a matter of convenience, I repeat, we must have names.

As above noted, it has been supposed that a rock might be

designated as a type which has certain characteristics. However, the only method of nomenclature which is logical is that which takes into account the fact of gradation and stages between all rock varieties; that types exist only as descriptions or specimens selected by man, not by nature; but abundance is determined by nature. All this is recognized in the scheme given. The definite forms which are selected for names are those which are abundant. This applies as well to the original forms of rocks as to their altered varieties. Had the varieties of rocks intermediate between those abundant kinds which have been given names been the abundant ones, rather than those to which names have been assigned, these would have been the rocks which should have been given names, and which in all probability *would have been given names* during the first period of the development of the science of petrography.

How shall demands for exactness be met?—But the question now arises as to how the demands of the petrographers for exactness shall be met without introducing a new independent name the moment a slightly different variety of rock is discovered, however small its mass. This demand may be met by the general application of special usages below given. The majority of the abundant kinds of rocks were early assigned names. To less abundant kinds of rocks intermediate between the more abundant kinds, names compounded from the simple names may be used; for example, granodiorite, trachydolerite, trachyandesite.[1] To either the simple or the compound names may be prefixed mineralogical qualifiers, thus further compounding them; for example, quartz-diorite, olivine-gabbro, analcite-basalt, augite-trachydolerite. With these simple or compound names, geographical qualifiers may be used. If the rock is so abundant and definite as to require a specific name, the geographical qualifier may be compounded with the more general name, as Hellefors-diabase. If, however, the idea is exactly to designate the rock occurring at a particular locality, without implying that

[1] Italian petrographical sketches, V, by H S. WASHINGTON: JOUR. GEOL., Vol. V, 1897, pp. 365, 366.

it is so abundant and important as to require a name to enter rock nomenclature, the geographical name may be used simply as a qualifier, as, Duluth olivine-gabbro. This usage gives the most exact discrimination without cumbering nomenclature with a multitude of independent names. In any of the foregoing classes of names the prefixes meta, apo, epi, schisto, gneisso, or other terms may be inserted for the altered rocks.[1]

Under the plan proposed we shall have coördinate simple names of about the value which Rosenbusch has designated as family for rocks which are the most abundant and important. We shall have compound names for rocks intermediate between the more abundant kinds. We shall have names with geological qualifiers, either compounded or not, as the case demands, for a further refinement in discrimination. In any of these three classes of names mineralogical qualifiers may be introduced as an additional discrimination. For all of the previous classes we shall have prefixes, with definite meanings, for the altered equivalents of the different rocks.

The method proposed is practically that of a binomial or trinomial nomenclature. The fundamental names would be based primarily upon abundance, and secondarily upon other factors. The secondary names would be introduced under the same principles.

Application of plan proposed.—How this plan can be worked out may be illustrated by some cases from recently described rocks. (1) *Nordmarkite*,[2] by Washington, is placed as equivalent to *mica-hornblende-quartz-syenite*. The rock is therefore a syenite. Assuming that this rock is sufficiently abundant so that it should have a place in nomenclature, it may be called *nordmarko-syenite*. In the same way, *akerite*[3] (augitic quartz-syenite) may be called

[1] In another place (Metamorphism, Monograph, U. S. Geol. Surv.) I shall discuss in detail the use of these terms. But in the present paper I do not wish to take up the subject. Here I wish merely to suggest a method of handling the altered rocks, rather than to discuss the details of its application.

[2] The petrographic province of Essex county, by H. S. WASHINGTON: JOUR. GEOL., Vol. VI, 1898, p. 799.

[3] JOUR. GEOL., Vol. VI, p. 796.

akero-syenite, if a new name is really necessary and preferable to augitic quartz-syenite. (2) The trachydolerites, designated by Washington as *ciminite*, *vulsinite*, and *toscanite*,[1] may be called *cimino-trachydolerite*, *vulsino-trachydolerite*, and *toscano-trachydolerite*. Under this usage *cimino*, *vulsino*, and *toscano*, take the same place with reference to the trachydolerites, that *hellefors*, *aasby*, *särna*, *ottfjälls* do to the diabases, as used by Rosenbusch (see p. ——). Indeed, Washington himself in one place speaks of *pulaskite* as *pulaskitic syenite*.[2] Following the plan proposed this would be *pulasko-syenite*. (3) As an illustration of the use of mineralogical terms compounded with names already compounded may be given *augite-toscano-trachydolerite*. If desirable, the order of the mineralogical and geographical parts of the name may be reversed. For instance, the leucite-trachytes, which Cross calls *orendite* and *madupite*,[3] may be designated *orendo-leucite-trachyte* and *madupo-leucite-trachyte*.

In all of these cases the geologist knows at once the general character of the rocks referred to. In the first case he knows the rocks are syenites; and, furthermore, that certain varieties of syenites are so abundant and so definite in character as to require a specific designation. In the second case he knows that there is a kind of rock intermediate between the trachytes and dolerites, and, if he knows what trachytes and dolerites are, he has a very clear conception of this rock without any further definition. He further knows that there are variations in the character of the trachydolerites which occur at particular localities, and which, in the opinion of the author, are so abundant and distinctive as to require specific designations. In the third case he further knows at once from the name that certain varieties of the Toscano-trachydolerite contain augite; and infers that this variety is exceptional. He knows that the leucite-trachytes have variations which are thought to be of sufficient importance to require specific designation.

[1] JOUR. GEOL., Vol. V, pp. 350–361.

[2] JOUR. GEOL., Vol. VI. p. 804.

[3] Igneous rocks of the Leucite Hills and Pilot Butte, Wyo., by WHITMAN CROSS: Am. Jour. Sci., Vol. IV, 1897, pp. 138, 139.

It is also self-evident that the extreme refinement practiced by Washington and Cross is in no respect lost by using the nomenclature proposed, rather than assigning independent names to particular varieties of rocks described. Indeed, the compound names proposed give additional refinement to that attained by independent names.

In giving the above illustrations I express no opinion as to whether the various syenites, trachydolerites, and leucite-trachytes are so abundant and important as to be worthy of specific names. This is a matter for the petrographer to settle. I merely use these terms as convenient illustrations as to how rock nomenclature can be handled so as to serve the purposes of the general geologist and the specialist, without throwing the subject of petrography into hopeless confusion.

Objection to long names.—The long terms resulting from the plan, as, for instance, augite-toscano-trachydolerite, may be objected to on account of their cumbersomeness and complexity. However, it may be said that these names are simple as compared with many of the names used in organic chemistry, and furthermore that they are justified on precisely the ground that the long names in organic chemistry are justified, that is, they are intelligible names. This is the fundamental point. The present method of naming rocks is not intelligible even to professional petrographers, and an unintelligible method can no longer be tolerated. The method proposed is intelligible to every geologist, whether a specialist in petrography or not, and gives at once the information desired by the general geologist and the extreme refinement demanded by the petrographer. The plan proposed gives all the advantages of generic, specific, and varietal names. If any petrographer can suggest a method of naming rocks which will better satisfy the demand of the petrographer for exactness, and of the geologist for intelligibility, I shall gladly favor such a plan rather than my own proposal.

Why petrographers have not generally followed plan outlined.—The plan suggested is so simple that the question immediately arises as to why petrographers dealing with igneous rocks have

not followed it. Was there not some good reason for the introduction during the past years of many new, independent names? The answer is, petrographers had not worked out any plan as to the naming of rocks, and to assign a new name for each new variety of rock was the easiest way out of the difficulty, although it was disastrous so far as their fellow workers were concerned. Then the honor of giving a new name to rock nomenclature doubtless had a too important effect. Furthermore, many of the petrographers still held, in a subconscious way, to the old notion of rock types, not yet having grasped the idea of general gradation.

Plan followed in case of sedimentary rocks.—That the scheme proposed is practicable is shown by the sedimentary rocks, where it has been substantially followed, although as a matter of necessity rather than a conscious system. In the sedimentary rocks, from the first, gradations were recognized, and hence the tendency to give each variety a new name never got any headway. To illustrate the application of the scheme to the sedimentary rocks, we may take the sandstones. There is an almost infinite variety of sandstones, but it so happens that petrographers have not been directing their energies to the minute discriminations of their variations, and we have not a dozen or score of different names for the different kinds of sandstone. Yet the sandstones of different localities are discriminated and recognized as different from one another by attaching the names of the localities at which the rocks occur to the name, and thus discriminating each rock from all others. For instance, in Wisconsin a peculiar sandstone occurring locally is called the Madison sandstone. From this designation the general geologist at once knows that this formation has the general characters of the rocks which have been called sandstone, and he will not go further. But if he is interested in the Madison district for some reason, scientific, economic, or otherwise, he may go further and learn the peculiarities of the particular sandstone which is found at Madison.

By this method the sedimentary formations are discriminated

the world over. However numerous the names for the sedimentary rocks may be in the future, the method still must be used, for however fine the discriminations resulting from such names, there will be variations from the meanings assigned to these names, and thus the local names are necessary.

In exceptional cases plan followed with igneous rocks.—The simple method proposed of designating the slightly different varieties of igneous rocks from one another, without throwing their nomenclature into hopeless confusion, has already been followed in several cases.

A notable instance is the term *Andendiorite* proposed by Stelzner[1] for a particular rock which has the general characters of a diorite, but which in some respects differs from ordinary diorite, and occurs in the Andes. A geologist who does not care to go into the detailed petrography of the region notes at once that in the Andes is a rock which has the general characters of the diorites, but which in some respects differs from the ordinary kind. He also at once knows that in the Andes is a rock which is different from the ordinary diorites, but which is allied to them. If in his investigative work he wishes to know exactly the meaning of the modifying term, he can do so by reading Stelzner's paper, or by obtaining specimens and an analysis of the rock. In the case of *Andendiorite*, the name has been also used as a new specific name, an dapplied by Iwasaki[2] to a somewhat similar rock in Japan. To a certain degree this shows how the method may be made to work out in practice in reference to the igneous rocks. When here and there other rocks are discovered similar or almost identical with the Andendiorite, and this variety of rock, as a result of these investigations, is found to be so abundant and so definite in its characters as to demand a specific name, the original word *Andendiorite* may be used for this purpose, or, better, a new specific name may be coined for it, and the rock be placed in the scheme of rock nomenclature.

Rosenbusch has used the method of geographical qualifiers

[1] A. STELZNER: Geologie und Paläontologie, von Argentina, p. 213.

[2] Andendiorite in Japan, by C. IWASAKI: JOUR. GEOL., Vol. V, 1897, pp. 821–824.

in a number o finstances precisely as proposed, for discriminating rocks. For example, he describes *helleforsdiabas*, *aasbydiabas*, *sarnadiabas*, *ottfjallsdiabas*.[1] Had some petrographers described these rocks perhaps we would have had four additional, independent names to remember, the value of which we would know absolutely nothing of, without any suggestion whatever as to the family, in Rosenbusch's sense, to which these new rocks belong.

The method proposed has unconsciously been followed to some extent by the United States Geological Survey. That organization has recognized that a sufficient number of independent names could not and should not be coined to designate every variety of rock. It has practically, if not by definition, recognized the endless variation and gradation throughout rock formations, by providing that *aqueous and metamorphic formations alike* should be given local names; for example, Chicopee-shale, Hoosac-schist, Becket-gneiss, etc.[2] This use of local names has furnished a more accurate method of discrimination than could be afforded by independent names. Moreover, only rocks which are present in some quantity have been given formation names. Thus, by practice at least, the idea of abundance as a factor in the naming of rocks has been recognized.

Suggestion to petrographers who have introduced new names.—In this connection it may be suggested that petrographers who have recently introduced new independent names would perform a service to geologists who are not petrographers, and to many other petrographers, by giving in subsequent papers equivalent names on the basis of the plan above advocated, to the special rocks to which they have given names. If this be done, the relative merits of the two plans will be tested. Within a short time it will be seen whether geologists and petrographers use the independent names or the more general names compounded with geographical and mineralogical terms. Where a new independent name was really needed, and performs a service in the

[1] Mikroskopische physiographie, II, Massige Gesteine, H. ROSENBUSCH; S. 219–220.

[2] Holyoke folio No. 50, Geological Atlas of the United States.

advancement of science, it will be sure to be retained. If it drops out of use, its proposal was premature.

Summary of advantages of proposal.—In conclusion, some of the advantages of the foregoing plan may be summarized:

1. The plan proposed serves all the purposes of nomenclature, from names of a general character to those giving the most minute discriminations. It has the advantage of grouping different varieties of rocks under terms, the general meaning of which is known to all. In the matter of nice discrimination it far surpasses the plan of independent new names for new varieties of rocks. It permits at once any difference in the character of a rock, however slight, to be discriminated, and it permits the growth of petrography by the grouping of the allied varieties together under a new specific name so soon as they shall have been found so abundant, so peculiar, or so important as to demand such a name. The professional petrographer will thus have a much more convenient and elastic nomenclature for describing rocks than he has at present. He may ignore minor differences between rocks in one sentence, and in the next sentence deal with the most refined differences between them. Thus the plan advocated meets both the demands of the geologist and of the specialist in petrography.

2. The plan proposed puts the available information of petrography in such shape that some master mind in the future may reduce the subject to a science. The present scheme of rock nomenclature makes it impossible for any person to get the facts clearly before his mind in such a way that they can be handled. The provisional scheme proposed accomplishes this end. If it be generally followed by petrographers, it is probable that within a few years it will be possible to propose a definite scheme of rock nomenclature, the terms of which correspond roughly to genus, species, and variety in biology.

3. It is believed, if once rock nomenclature be placed upon a reasonable basis, that this will be a great step toward the establishment of a satisfactory scheme of rock classification.

4. Under the plan suggested it will be easy for the student

to get definite notions of the common kinds of rocks. Having this knowledge, he knows without explanation the meaning which is to be attached to a name compounded of two of them. He knows without a moment's reflection the meaning of a mineralogical qualifier prefixed to a noun. He knows that a geographical qualifier means the particular variety of rock which occurs in a certain district. Thus it will be possible for a student to gain a comprehensive knowledge of the chief kinds of rocks at a very early stage of work, and to supplement his general knowledge by details as his work advances.

5. A further advantage of the foregoing plan will be that many of the earliest rock names proposed will be retained, although some may be abandoned. The reason why so many of the old names will be retained under the plan proposed is that many of the abundant rocks were first found; for, as already noted, while the petrographers supposed they were following the plan of naming rocks on the basis of types, they were largely following the plan of naming rocks on the basis of abundance.

6. Still another of the manifest advantages of the plan is that it throws the emphasis on the proper thing; it calls attention to the common, not to the exceptional, rocks. Many petrographers, in discussing the rocks of an area, describe with the utmost particularity the minute characteristics which are peculiar to the exceptional rocks of the district or region, and say comparatively little of the common rocks which compose the great mass of the rocks of the area. Of course, there is some justification for this, in that the characters of the common forms are known. But all papers describing the geology of a region should be so framed as to give a clear conception of the common kinds of rocks which are preponderant, and indicate that the exceptional things described in such detail are only so described because of their peculiarities. To the reader in some way should be conveyed the idea of the relative abundance of the rocks. The error of emphasizing the exceptional and overlooking the common phenomena has been one of the most pernicious mistakes which runs throughout geological papers and text-books. For instance,

many pages in a text-book are given to a discussion of earthquakes, and only a small fraction of that space is given to the vastly more significant, slow earth movements which occur without earthquakes or with earthquakes as secondary phenomena.

7. Finally, the foregoing plan has one further advantage. It emphasizes a great law of nature, the law of gradation—the principle that ultimately there is no such thing as an absolute type. In this respect, petrography, if it will but use its opportunity, has an advantage over any other subject. In biology there have once been gradations between species, between families, between classes. Many of these gradations have been destroyed in the course of evolutionary processes. However, in petrography all of the gradations yet persist, and thus it furnishes the best illustration of the principle of gradation, a fundamental principle of nature.

C. R. VAN HISE.

MADISON, WIS.,
November 1899.

EDITORIAL

A PROPOSED INTERNATIONAL JOURNAL OF PETROLOGY.—The committee appointed by the Seventh International Congress of Geologists to consider plans for the establishment of an International Journal of Petrology has chosen Professor F. Becke of Vienna, well known as the editor of *Tschermak's Mittheilungen*, President of the Committee, and has taken the first steps toward the organization of such a journal. It has been proposed that articles appearing in it shall be printed in French, German, or English at the option of the author.

While primarily intended for the publication of reviews and abstracts of all petrographical papers wherever published, it is suggested that it may include also articles which shall appear in it for the first time. The carrying out of this must depend upon the financial support the journal receives.

The journal is to be managed by a committee appointed by the International Congress of Geologists, the committee to select an editor who shall have two assistants ; the editor and assistants to receive salaries for their services.

The desirability of having one source, thoroughly up to date, to which to turn for information concerning all matters published on petrology is self-evident to all attempting to keep abreast with the rapid advance of this science. One has only to observe what a great impulse to the science of mineralogy has been given by the establishment of Groth's *Zeitschrift für Krystallographie*, to be convinced of the usefulness and convenience of such a journal.

The necessity of forecasting as correctly as possible the financial support obtainable for such a journal has suggested to the American members of the committee the plan of calling attention to the enterprise and of inviting all interested in its success to communicate to either of them such suggestions or information as may aid in estimating the amount of annual

subscriptions or contributions that may be obtained from this country.

It is expected that the chief support will come from individual subscriptions and from university and public libraries, but it may be possible to obtain assistance, in the first years of the undertaking at least, from other sources.

J. P. IDDINGS,
L. V. PIRSSON,
Members of the Committee for America.

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DO STATE SURVEYS PAY? The question has often been asked, and in the coming legislative season probably will be asked many times. An answer is usually desired which deals with dollars and cents, but, perhaps, a partial answer may be given by noting the sort of requests for miscellaneous information which consume a not unimportant portion of the time of survey officers.

For illustration, the requests of a single day in the office of one of the smaller surveys may be noted. Two came in the morning mail. The first was from a professor in one of the smaller colleges, asking for twenty copies of a certain pamphlet to use in the class room. The second was from a consulting chemist, retained by some eastern capitalist to investigate the advisability of establishing an important manufacturing plant in the state. He wished to know the amount, quality, and average cost of certain ores which were being mined there, and the probability of larger quantities being mined. A third request was made in person, by the engineer in charge of locating an important line of railway. He wished a report upon the mineral resources of all kinds along the proposed line. A fourth request came in the afternoon mail. It was from a high-school teacher, who wished for a certain report to use in teaching. The last request was from a reporter, sent to secure an interview relative to certain reputed iron deposits that the local papers of a certain section of the state were making much of. The city editor of a big daily wished to know whether there was any iron there. If so, how much. What was its quality, and what the chances of securing its development if proper publicity were given the matter. He wanted "facts which could be relied on," and so he sent to the survey.

All these requests were attended to in detail, and the tired official wondered when he was to get time to write, revise, and print the report on the year's field work.

H. F. B.

SUMMARIES OF CURRENT NORTH AMERICAN PRE-CAMBRIAN LITERATURE.[1]

DAVIS,[2] in connection with an account of the Triassic formation of Connecticut, maps the boundary between the Triassic and crystalline rocks to the east and west. The prevailing monoclinal faulted structure in the Triassic involves a similar structure in the crystallines below, and it is believed that the structure observed in the Triassic is due to the slipping of large slabs of the crystalline rocks and the overlying Triassic rocks, in such way that each slab was elevated with reference to the slab next to the west, or, lowered with reference to the one next to the east. The explanation of the cause of the faulted structure is the same as that offered in a previous paper.[3]

Merrill[4] gives a general account of the geology of the crystalline rocks of southeastern New York.

The crystalline rocks lie on the east of the Hudson River, in New York, Westchester, Putnam, and Dutchess counties, whence they extend into Connecticut; and on the west of the river, in Orange and Rockland counties, whence they extend southwesterly into New Jersey. The lowest member is a coarse hornblende-granite which forms the central mass of the range of mountains known as the Highlands of the Hudson, and, in their highest peak, Breakneck Mountain, is exposed through a vertical height of nearly 1200 feet. Other granites, nearly free from hornblende, occur in subordinate masses. The granites are probably igneous and of great age. On their flanks are banded gneisses, the Fordham Gneiss, consisting chiefly of quartz and orthoclase, with biotite and hornblende, and containing numerous beds of magnetic iron-ore. The gneisses on the south side of the Highlands extend through Westchester county in a series of folds with southwesterly trend, and on the northern slope of the Highlands, at several

[1] Continued from p. 425, Vol. VII, JOUR. GEOL.

[2] The Triassic formation of Connecticut, by WM. M. DAVIS: Eighteenth Ann. Rept. U. S. Geol. Surv., Part II, 1898, pp. 1–192. With geological map.

[3] The Structure of the Triassic Formation of the Connecticut Valley, by WM. MORRIS DAVIS: Seventh Ann. Rept. U. S. Geol. Survey, 1888.

[4] The geology of the crystalline rocks of southeastern New York, by F. J. H. MERRILL: Report of the New York State Museum, 1896, pp. 21–44.

places in Dutchess county, are overlain unconformably by quartzites, which are believed to be of Cambrian age.

Ries[1] describes the geology of Orange county, New York. Pre-Cambrian rocks form the Highland region in the eastern part of the county, the northwestern side of Bellvale Mountain, and a series of rounded knob-like hills extending from Sugar Loaf village to Newburgh. They comprise gneiss, at times massive and resembling granite and limestone. The crystalline rocks are folded and faulted, the folds plunging frequently to the northeast.

In the south-central part of the county is found an area of white and blue limestone, which continues south into New Jersey. The white limestone is found in New Jersey to contain fossils of Cambrian age. Exposures are found east of the road, 1¼ miles west-southwest of Pine Island station, which show the passage of the blue into the white limestone. Other, similar areas of limestone are found to the northeast.

Limestones interbedded with the gneisses are found at Popolopen Pond, and again at Fort Montgomery.

Wolff and Brooks[2] present a final discussion of the age of the Franklin white limestone, of Sussex County, N. J. The pre-Cambrian age of the white limestone is believed to be shown by the following facts:

The supposed cases of interbedding of the white limestone and the Cambrian quartzite are found to be due to faulting, or to peculiar conditions of deposition. On the other hand, while it is difficult to prove that the white limestone and pre-Cambrian gneiss are actually interbedded, narrow bands of the true gneiss do occur within the white limestone belt, and seem to be an integral part of the series.

The granite occurring in the area is intrusive in the white limestone, and the nature of the contacts of the granite and the Cambrian quartzite indicates that the intrusion was prior to the deposition of the Cambrian quartzite and blue limestone. While the intrusion of the granite has caused local metamorphism of the white limestone, it is believed that the crystallization of the limestone antedated the granitic intrusion, and was contemporaneous with the crystallization of the gneisses in their present form.

[1] Geology of Orange county, by HEINRICH RIES: Forty-ninth Ann. Rept. of N. Y. State Museum, for 1895, Vol. II, 1898, pp. 395–475. With geological map.

[2] The age of the Franklin White limestone of Sussex County, N. J., by J. E. WOLFF and A. H. BROOKS: Eighteenth Ann. Rept. U. S. Geol. Surv., Part II, 1898, pp. 425–457. With geological map.

The structural relations of the three belts of Cambrian blue limestone with the gneiss and white limestone are such as to indicate unconformity. Along the normal contacts of the blue and white limestone the quartzite intervenes between the two. The bedding of the blue limestone and underlying quartzite is everywhere conformable, while the dip of the foliation of the white limestone and the gneisses is discordant with this bedding.

Isolated patches of Cambrian quartzite are found within the white limestone area. In one place a crevice in the white limestone is filled with the Cambrian quartzite containing undoubted pebbles of the white limestone.

Comment.—The results above presented bear evidence of close and careful field study. The pre-Cambrian age of the white limestone is clearly proven, thus satisfactorily disposing of a much disputed question.

There now remains the question of the origin of the gneisses. In this connection attention may again be called to the marked similarity of the limestones and associated gneisses of the New Jersey area, to the pre-Cambrian limestones and associated gneisses of the Adirondack and Original Laurentian districts to the north. In a general way it would seem that the story worked out for one of the districts may perhaps apply to the others.

Weidman[1] describes the pre-Cambrian igneous rocks of the Utley, Berlin, and Waushara areas, in the Fox River Valley of Wisconsin. They range from volcanic flows to masses of deep-seated origin, with corresponding textures. The rock of the Utley area is a metarhyolite, at Berlin a rhyolite-gneiss, and in the Waushara area a granite. Analyses of the rocks of the three areas show a close similarity in chemical composition, and it is believed that the rocks represent phases of a single parent magma. The rocks have been metamorphosed to different degrees, and the results of the metamorphism, particularly of the feldspars, are described in detail.

The crystalline rocks are unconformably overlain by flat-lying Potsdam and Ordovician sediments. From their similarity in composition to the Baraboo volcanics, which are considered to be of Keweenawan age, it is believed that they belong to the same province, and are therefore of Keweenawan age.

[1] A contribution to the geology of the pre-Cambrian rocks of the Fox River Valley, Wis., by SAMUEL WEIDMAN: Bull. Wis. Geol. & Nat. Hist. Surv., No. III, 1898, pp. 63.

Norton,[1] in a description of the artesian wells of Iowa, discusses the attitude of the Algonkian floor. In the northwestern part of the state the Algonkian outcrops as the Sioux quartzite. From here it sinks rapidly to the south and east, and is discovered near the area of its outcrop only by the steep wells at Sioux City, Hull, and Le Mars. In the east-central part of Iowa is a slight elevation of the Algonkian floor, disclosed by the artesian well at Cedar Rapids. In Wisconsin the Algonkian outcrops as the Baraboo quartzite, a rock similar to the Sioux quartzite. From this outcrop the Algonkian sinks gently to the southwest, as it is reached by the drill at Lansing, Iowa. At no other place in Iowa has the drill gone deep enough to reach the crystalline rocks.

Comment.—The connection of the crystallines reached by the drill with the Algonkian outcrops of Iowa and Wisconsin is conjectural, and perhaps it would be better not to assume that such crystallines are all Algonkian. However, the observations are of interest as showing the attitude of the ancient crystalline floor, whether Archean or Algonkian.

Beyer[2] maps and describes the part of the Sioux quartzite formation exposed northeast of Sioux Falls in sections 10, 11, 14, 15, 22, and 23, T. 102 N., R. 48 W., South Dakota. The quartzite dips from 3° to 7° to the southwest. An accurate estimate of the thickness may not be given, but 1500 feet is a liberal one.

Slate is exposed in the area in isolated outcrops, but never in contact with the quartzite. In composition it corresponds very closely to the quartz-slate of Irving and Van Hise.[3] Intruding the slate are diabase dikes, which have followed the bedding.

The relations of the slates and quartzites cannot here be ascertained. However, from the relations of the two outside of the area it is believed that the slates are the upward continuation of the quartzite, and that they have been removed in large part.

The age of the Sioux quartzite is believed to be pre-Cretaceous. Its reference to the Huronian may be supported by the following facts: The lithological characters of the quartzite are identical with those of

[1] Artesian wells of Iowa, by W. H. NORTON: Geol. Survey of Iowa, Vol. VI, 1897 (The Algokian, pp. 139–140).

[2] The Sioux quartzite, and certain associated rocks, by S. W. BEYER: Iowa Geol. Survey, Vol. VI, 1897, pp. 69–112.

[3] The Penokee iron-bearing series, by R. D. IRVING and C. R. VAN HISE: Tenth Annual Rept. U. S. Geol. Survey, 1890, p. 370 et seq.

the Baraboo quartzite in Wisconsin, which has been referred by Irving and Van Hise to the Huronian. The diabase intruding the slate, supposed to be the upward continuation of the quartzite, is strikingly similar to intrusives which are peculiar to the Huronian in the Lake Superior region.

Frazer[1] sketches the geology of an area in the vicinity of Galena, in the Northern Black Hills of South Dakota. Mica-schists, thought to be upper members of the Archean, are found striking northeast-southwest, and dipping at angles from 38° to 85°. They are generally micaceous and coarse-grained, but vary greatly, sometimes passing into nacrite- or hydromica-schist, and sometimes, though more rarely, assuming a heavily bedded character reminding one of gneiss.

Todd[2] reports on a section across the Black Hills from Rapid City westward. The alternating slate and quartzite beds of the Algonkian were found to be folded in a most intricate fashion. A number of the folds were worked out. In most cases the lamination and stratification seem to correspond in direction.

Comment.—The last observation differs from one made by Van Hise, who, as a result of work done in 1890, concluded that the prominent foliation of the Black Hills is independent of the bedding, and as a rule cuts across it.

Griswold[3] describes the geology of Helena, Montana, and vicinity.

Middle Cambrian, or Flathead, quartzite forms an important part of the ridge stretching from Helena southeast to Montana City, and northwest, west, and south around Mount Helena. The sedimentary rocks underlying most of the area of the city, on the north side of this Cambrian quartzite, are classed as Algonkian. The Algonkian rocks vary from clay-slates to micaceous, sandy, or calcareous slates, which often become quartzites or limestones. The Algonkian slates seem to conform to the overlying strata in the dip of their beds. As there are many small folds, it is difficult to determine the thickness; 5000 feet does not seem too large a total.

Gilbert[4] maps and describes the geology of the Pueblo quadrangle,

[1] Notes on the Northern Black Hills of South Dakota, by PERSIFOR FRAZER: Trans. Am. Inst. Min. Engineers, Vol. XXVII, 1898, pp. 204–228.

[2] Section along Rapid Greek from Rapid City westward, by J. E. TODD: South Dakota Geol. Survey, Bull. No. 2, 1898, pp. 27–40.

[3] The geology of Helena, Montana, and vicinity, by L. S. GRISWOLD: Journal of the Association of Engineering Societies, Vol. XX, 1898, pp. 1–18.

[4] Geol. Atlas of the U. S., Pueblo folio, No. 36, by G. K. GILBERT: U. S. Geol. Survey, Washington, 1897.

including part of Pueblo county and the southeast corner of Fremont county, Colorado. Archean rocks occupy two small tracts in the southwestern part of the quadrangle. The more abundant kinds of Archean rocks are mica-schist, mica-gneiss, and granite. The schists and gneisses strike north to northwest, and are nearly vertical. Their origin is not known. The granite is intrusive in the schists and gneisses.

The Archean rocks are overlain unconformably by Paleozoic and Mesozoic sediments.

Lakes[1] sketches the geology of the Gunnison gold belt in Gunnison county, Col., from the Cebolla River on the west to the head of Taylor Park and the Sawatch range on the east. The northern part of area is included in the granitic system of the Sawatch range. The southern part is occupied by schists and gneisses, underlain by coarse massive granite. The schists and gneisses are of pre-Cambrian age, but whether Algonkian or older has not been determined. The contact of the schists and gneisses with the underlying granite is an eruptive one, the granite containing fragments of the schist, giving the impression that the schists had been floated up on an underlying molten or semi-molten sea of granite. Cutting the schists are occasional dikes of diabase and possibly basalt and andesite, and resting on the eroded edges of the schists are various later overflows of andesitic breccia, rhyolite, trachyte, and basalt.

Aguilera[2] gives a synopsis of the geology of Mexico. The most ancient, or Azoic, rocks are granites, gneisses, and schists, presenting many variations. They extend lengthwise along the Pacific coast, forming a narrow band, interrupted in places, and sending ramifications toward the central part of the country, in some places almost to the eastern coast. They occupy the southern part of the state of Puebla, a part of the Sierra Madre Mountains in Chiapas, and extensive portions of Oaxaca and Guerrero; they are found also in Zacatecas, around Fresnilo; in Guanajuato, in the vicinity of the capital; in Sinaloa, around the crests of the Sierra Madre; in Sonora, in its northwestern and western parts; in lower California, where

[1] Sketch of a portion of the Gunnison gold belt, including the Vulcan and Mammoth Chimney mines, by ARTHUR LAKES: Trans. Am. Inst. Min. Engineers, Vol. XXVI, 1897, pp. 440–448.

[2] Sinopsis de Geologia Mexicana, by JOSE C. AGUILERA: Bol. del Inst. Geol. de México, Nums. 4, 5, & 6, 1897, Part II, pp. 189–250. With geol. maps.

they constitute the central Cordilleran axis of the peninsula; in Vera Cruz, in its western region, limited by Puebla, in the canton of Zongolica.

In the southern part of Puebla, and in Guerrero and Oaxaca, where the greater part of the exposures occur, the sequence is as follows, from the base up: (*a*) Porphyritic gneiss, similar to augen-gneiss, at the base losing its lamination and passing into a kind of granite. (*b*) Phyllite-gneiss, resting upon, and grading below into preceding beds. (*c*) Very abundant mica-schist, in some places garnetiferous, and in perfect conformity with the phyllite-gneisses. (*d*) Phyllites, very argillaceous in the upper part, and showing gradual diminution in the proportion of clay toward the base. In accordance with this change of composition, the structure varies from perfectly schistose to laminated, and finally to stratiform.

After the deposition of the argillaceous phyllites, and before the termination of the Paleozoic, there have occurred numerous eruptions, in order of age as follows: Granite-gneiss, granite, granulite, hornblende granite, pegmatite, greisen, and diorite.

Comment.—The ancient rocks are mapped as Azoic, and in the text are described as Archean and Primitive, so that these three terms are used in the same sense, to cover all rocks below the Paleozoic. The pre-Paleozoic rocks are both sedimentary and igneous, and not improbably may represent the Algonkian as well as the Basement Complex.

C. K. LEITH.

MADISON, WIS.

Reviews

Geology of the Yellowstone National Park. Part II. Descriptive Geology, Petrography, and Paleontology. By ARNOLD HAGUE, J. P. IDDINGS, W. H. WEED, C. D. WALCOTT, G. H. GIRTY, T. W. STANTON, and F. H. KNOWLTON. Washington: Government Printing Office, 1899. Pp. xviii + 893, 121 plates and 4 figures. Monograph XXXII of the United States Geological Survey.

This compendious monograph is about equally divided between petrography and paleontology, having about 440 pages of text in each division, and of the 121 plates 62 are given to fossils, and 59 and the four figures to petrography and geology. Of the fourteen chapters Iddings furnished seven on the petrography, Iddings and Weed two on the geology, Weed and Hague each one on the geology. Walcott's work on the Cambrian fossils and Girty's on the Devonian and Carboniferous go into one chapter. Stanton furnishes one on the Mesozoic fossils and Knowlton one on paleobotany.

The first chapter, by Iddings and Weed, is on the descriptive geology of the Gallatin Mountains, which mountains extend eighteen miles within the boundary of the park. The diversity of the geological features in this area is remarkable. The sedimentary rocks begin with the Cambrian and range through the Silurian, Devonian, Carboniferous, and Juratrias into the Laramie division of the Upper Cretaceous. Cutting through the sedimentary series are intrusions of igneous masses in the form of laccoliths, sheets, and dikes. The sedimentary rocks are slightly folded and strongly faulted. Extensive erosion has exposed large areas of the rocks in their structural relations. To still add to the diversity, the surface has been glaciated.

The second chapter describes the intrusive rocks of the Gallatin Mountains. These consist mainly of fine-grained, aphanitic masses, mostly porphyritic and andesitic in character. The Indian Creek laccolith is hornblende-mica-andesite-porphyry. The Bighorn Pass sheet

consists of kersantite of complex composition; the Gray Mountain mass and connected sheets consist of andesite and andesite-porphyries. The Mount Holmes bysmalith, Gallatin River laccolith, and the Bunsen Peak mass are composed of dacite-porphyry.

Chapter three deals with Electric Peak and Sepulchre Mountain, which are described as parts of a Tertiary volcano faulted across the neck with a vertical throw of more than 5000 feet. The deeper parts of the volcano consist of sedimentary strata cut by dikes, sheets, and the stock or conduit of the volcano. The ejected breccia and lava flows, along with the upper portion of the conduit, make up Sepulchre Mountain. The andesitic lavas of Sepulchre Mountain change to diorites and porphyries in Electric Peak. Rocks with the same chemical composition in one place crystallize into diorites and in another place form andesites. Both types are illustrated by photomicrographs and photographs. Maps and section illustrate fully the relations of the different rocks.

The northern end of the Teton range, which occurs in the southern part of the park, is described at length in the next chapter. This range is made up of a nucleus of crystalline schists and gneisses, which are overlain by flexed and faulted Paleozoic and Mesozoic strata. The eroded edges of these old sedimentary rocks were covered with volcanic basic breccias and after another period of erosion an extensive outflow of acidic lava covered the whole area and still conceals the northern extremity of the Teton Mountain.

Mr. Hague, in chapter five, describes the irregular diversified mountainous area known as Huckleberry Mountain and Big Game Ridge. It lies in the southern part of the park and in the Forest reservation and consists of a number of northwest-southeast ridges, composed mostly of Mesozoic rocks. The Cretaceous sandstones are the prevailing rocks, but small areas of older strata are exposed. The rhyolites of the park plateau abut against the slopes of the upturned edges. Besides Huckleberry Mountain and Big Game Ridge, there are other elevations known as Wildcat Peak, Bobcat Ridge, Chicken Ridge, and Two Ocean Plateau. The principal igneous rocks in the area are dacites, surrounded by apparently younger rhyolite. In the gorge of the Snake River the Madison limestones, Teton sandstones, Ellis limestones, and shales are exposed. The Snake River hot springs occur near the contact of the rhyolite with the limestones. The travertine deposits around the springs resemble those around the Mammoth Hot Springs

nd the lime is derived from the Madison limestone. The Laramie trata are exposed near the base of Pinyon Peak, as shown by the charcteristic Wolverine flora. The conglomerate of Pinyon Peak is probbly Eocene, as it underlies the basic breccias of the Absaroka range and verlies unconformably the Laramie sandstones. Outlet Canyon, the icturesque gorge cut through Chicken Ridge, at one time served as an utlet into Snake River for the waters of Yellowstone Lake. The Yelowstone Canyon now furnishes an outlet for these waters into the tlantic, instead of into the Pacific. Two Ocean Plateau, which rises 0,000 feet above the sea level, forms a part of the Absaroka Range. t is made up of volcanic breccias and tuffs.

Chapter six describes the southern end of the Snowy range, which orms the northeast corner of the park. It consists of a broad core of rystalline rocks, bordered by Paleozoic rocks, which dip away from the rystalline axis. Detailed sections of the Paleozoic sedimentary rocks re given, but the igneous rocks are described in other chapters.

Chapter seven is especially interesting to petrologists, as it describes n detail the structural features and petrographic characteristics of a issected volcano in the Crandall Creek basin. It lies on the border of ne park forest reservation and east of the park proper. The great alue to petrology lies in the clear delineation of the inside of a volcano, nd in giving additional field evidence of the gradation of coarsely rystalline so-called Plutonic rocks into the glassy eruptives. "The oarsely crystalline gabbros and diorites, with smaller bodies of granite, xposed for a height of 3000 feet, are plainly seen to have been intruded nto a vast accumulation of basaltic tuff and scoriaceous breccia. From this oarsely crystalline mass as a center, dikes of fine-grained rock peneate the surrounding lavas in all directions, the dike rocks becoming ne-grained rapidly as they leave the once heated core. They form a etwork of branches which connect the outlying aphanitic and characterticaIly volcanic rocks with the more crystalline dikes near the core hich finally merge into the granular body of the gabbro and dorite." he whole forms one complex network so closely interwoven that the abbros of the core are as truly volcanic as the glasses on the surface. he volcano has built itself upon a ridge of eroded Paleozoic rocks, nd beneath the volcano are remnants of Eocene breccias and lava ows.

The next chapter treats of the Absaroka range which consists mainly f volcanic breccias with smaller quantities of massive flows. It contains

an account of their field occurrence and distribution, and a systematic description of their mineralogical composition and characteristics. The oldest rocks occur at the north end and consist of acid breccias found in remnants underlying early basic breccias. The former consist mainly of hornblende-andesite and hornblende-mica-andesite. The basic breccias consist of pyroxene-andesite, passing upward into basalt. Upon these were thrown other acid breccias, similar in composition and appearance to the earlier ones. These grade upwards into later basic breccia, consisting of andesites with less basalt than occurs with the earlier flows. This last basic breccia forms the southern portion of the range within the park and also the Two Ocean Plateau. Remnants of surface flows of massive andesite form the summits of Mt. Stevenson, Mt. Doane, Colter Peak, and several prominent mountains south of Sylvan Pass.

Chapters nine, ten, and eleven discuss different classes of the volcanic rocks. The Absarokite-Shoshonite-Banakite series consists of certain basaltic and other rocks associated with andesitic breccias and basalt flows which have considerable orthoclase and a comparatively high percentage of potash. They occur as lava flows and dikes in various localities. They have been classified according to their chemical and mineral composition.

The rhyolites in the park are almost wholly extrusive lavas of uniform chemical composition, but differing widely in color, texture, and megascopic habit. The mode of occurrence, and the microscopic features of phenocrysts, spherulites, lithophysae, are described in detail, and beautifully illustrated. The modifications of crystallization, lamination and the formation of pumice are referred to heterogeneity of the molten magma, especially with reference to the amount of vapors contained in it. In some places basalt appears to have been inclosed and partly fused by the rhyolite.

The recent basalts are distinguished from the early brecciated ones by being ophitic and non-porphyritic. They overlie the rhyolite in most cases, but in some places they occur beneath it, and in some places between the older and younger sheets of rhyolite.

With chapter twelve begins the paleontologic part of the work. The Director of the survey describes the Cambrian fauna from which twenty-one species have been obtained. Several of these are new, and are here described and illustrated for the first time. No fossils of undoubted Silurian age have been obtained. The Devonian is

represented in the Three Forks limestone. A varied but wholly Lower Carboniferous fauna has been obtained from the Madison limestone.

In chapter thirteen Mr. Stanton describes the Mesozoic fossils. These were obtained from the Gallatin range, near Electric Peak, Teton range, in the vicinity of Wildcat Peak and Huckleberry Mountain, and from the Cretaceous ridges in the southern end of the park and Yellowstone Forest Reserve. There are seventy-eight invertebiates, one of which is supposed to be of Triassic age, forty-six are Jurassic, and thirty-two are Cretaceous. The fossils are mainly from the Ellis division of the Jurassic and the Colorado of the Cretaceous.

The last chapter, by Mr. Knowlton, on the fossil flora, is a long one, covering 233 pages, besides 45 plates of illustrations. The Mesozoic flora is confined to the Laramie sandstones of the Cretaceous, and is found on Mt. Everts, near Mammoth Hot Springs, and at the base of Pinyon Peak, near the head of Wolverine Creek. The Tertiary flora is quite varied, and full of biological interest. On comparing it with the present it signifies great climatic changes since the Miocene. It is found in numerous localities associated with the breccias and silts of the igneous rocks, where the muds and silts furnished a soil favorable to plant growth. The Tertiary fossil flora embraces about 150 forms in thirty-three orders. The interesting fossil forest trees of Specimen Ridge are illustrated with photographs of the trees in the field and enlarged microscopic sections showing the cellular structure.

The petrographical and paleontological features of the Yellowstone National Park are certainly described in great detail, and the monograph will no doubt prove to be a valuable handbook to scientists, especially to those visiting the region.

T. C. H.

Report on the Geology and Natural Resources of the Area included by the Nipissing and Temiscaming Map Sheets, comprising portions of the district of Nipissing, Ontario, and of the county of Pontiac, Quebec. By ALFRED ERNEST BARLOW. Geological Survey of Canada. Part I, Annual Report. Vol X, 1899, pp. 302.

This report, accompanied by two well-executed maps on a scale of four miles to the inch, and covering an area 6912 square miles of the northern Protaxis of the Dominion of Canada, is a valuable addition to the literature of the pre-Cambrian of North America and is a further

installment of the work which is being systematically carried for
by the Dominion Geological Survey on these older rocks. The
maps, constituting what are known as sheets Nos. 131 and 138 of
Canadian Series, lie in the Upper Ottawa district along the borde
the two Provinces of Quebec and Ontario, and comprise portion
both. Lake Nipissing and Lakes Temagami, Temiscaming, and K
pawa, as well as many smaller bodies of water, are included in
area, and afford along their shores especially good opportunities
the prosecution of geological work.

After presenting a general account of the early explorations in
region, some of which date back almost to the time of the earl
settlement of the country by the French, and of previous surveys,
physical features of the country are described. The area is a g
uneven, or gently undulating, rocky plateau, sloping somewhat to
east and southeast, having a general elevation of 900 to 1200
above sea level, the level being so nearly uniform that hills 50 to
feet higher are conspicuous topographical features. This peneplai
traversed in a north and south direction along one line by a very d
and narrow rocky gorge, in which lie Lake Temiscaming and the Ott
River. The hills, or cliffs, rise to a height of 400 to 600 feet from
water on either side, while the water of the lake is 400 feet deep;
bottom of the gorge being filled with a fine silt. The depressio
thus at least 1000 feet deep and represents a great canyon simila
those which are found on the margin of the northern Protaxis a
many other points. Several smaller rivers also occupy similar dep
sions. "The detailed examination of the region, however, am
demonstrates that the sculpturing to which the surface owes its pre
configuration was practically completed long before the advent of
glacial epoch, and that the main valleys, especially those of the Ott
and Mattawa rivers, were in existence long prior to the deposition
the Palaeozoic sediments." With the exception of some comparati
small areas occupied by Palaeozoic outliers, ranging in age from Bl
River to Niagara, the district is underlain by rocks of Laurentian
Huronian age. The Laurentian, with the exception of a few sm
occurrences, is represented exclusively by the fundamental gneiss
mass of granitic and dioritic rocks, usually possessing a folia
structure in which are many streaks, bands, or inclusions of b
character, allied to diorites or diabases in composition, and represe
ing either basic segregations from the granitic magma or portions

basic intrusions caught up in it. This fundamental gneiss, it is believed, probably represents the original crust of the earth which has undergone successive fusions and re-cementations before reaching its present condition. In placing these rocks at the base of the series it is not intended to assert that they stand for any distinct or prolonged period of geological time, nor to affirm that these rocks, in their present condition and with the foliation which they now possess, antedate those of the Huronian system. This, as is shown, is not the case in many, or even probably in most, instances.

The chemical and mineralogical composition of the gneisses, as well as the character and origin of their foliation and the genetic relation of their associated pegmatites, are considered at length, and many interesting facts brought forward which cannot here be further discussed.

The Grenville series, so extensively developed further south, is in this northern area represented only by a few very small and unimportant occurrences of highly crystalline limestone and a single occurrence of gneiss. They occur isolated from one another and surrounded by fundamental gneiss on every side, and are referred to the Grenville series on account of their identity in petrographical character with the areas of this formation immediately to the south.

The district also includes large tracts of country underlain by pyroclastic and epiclastic rocks, forming a northeasterly extension of the development of the "typical" Huronian area on the north shore of Lake Huron. At one place on Lake Temiscaming, these Huronian rocks are found resting upon the floor of fundamental gneiss on which they were originally deposited, and of whose detritus they are made up, everywhere else the fundamental gneiss has been refused or softened and penetrates the superincumbent Huronian. The total thickness of the Huronian in the area is about 1800 feet, made up as follows: 1. Breccia-Conglomerate, 600 feet. 2. Shales and slaty greywackes, 100 feet. 3. Quartzose grit or Arkose, 1100 feet. Associated with these Huronian sediments are numerous intrusions of gabbro and diabase, some of which pass over gradually into flesh-red granites, representing, it is believed, portions of one and the same magma.

No attempt is made in this report to correlate the Grenville series and the Huronian of the area, as the facts are insufficient to warrant the attempt. And it may be remarked incidentally in this connection that a statement, made on page 415 of the current volume of this

JOURNAL, in reviewing some other recent papers on the Canadian Cambrian, is scarcely correct. The statement is as follows :

"The succession and correlation proposed in the above paper Adams and Barlow and by Ells are fundamentally different from traditional one which has been held in Canada for many years. first departure is in placing the Grenville and Hastings series equivalent to the Huronian."

In the papers in question this correlation was not definitely m but it was stated in reference to the Hastings series that "b lithologically and stratigraphically the rocks bear a striking resembla to rocks mapped as Huronian in the region to the north and no east of Lake Huron, and it seems very likely that the identity of two series may eventually be established. The two areas, howe are rather widely separated geographically, and the greatest care have to be exercised in attempting such a correlation."[1]

The further statement made by the reviewer that "Ells places the Huronian all the sedimentary rocks of Eastern Canada" is manifestly inaccurate, seeing that while it might terminate the c troversy concerning the upward extension of the Huronian to incl in that system the whole Palaeozoic succession, Ells cercainly did advocate this course.

The Palaeozoic outliers in this area and especially that of Niag age are of exceptional interest. Geographically this outlying patc Niagara is so widely separated from any other locality where rock this age are now known to exist, that it has been a question as to whet it was formerly connected with the occurrences about Hudson Ba with those about Lake Ontario. The strata are highly fossilifer and the palaeontological evidence presented seems to prove that seas in which the Niagara sediments of the Winnipeg basin and Hudson Bay were deposited were practically continuous, while b were separated from the Temiscaming basin and the region to southwest.

The Pleistocene history of the region seems to consist of a per of glaciation by a great ice-sheet, followed by a profound submerger during which time the ocean invaded a large portion of the Otta valley forming a marine gulf rivaling in extent the similar invasi of the sea in Palaeozoic times. The direction of motion of the varies from S 7° W to S 18° W.

[1] American Journal of Science, Vol. III, March 1897, p. 177.

The report also contains much information concerning the fauna, flora, and timber resources of the district, and has appendices giving lists of elevations and catalogues of the Palaeozoic fossils.

FRANK D. ADAMS.

The Paleozoic Reticulate Sponges Constituting the Family Dictyospongidae. By JAMES HALL and JOHN M. CLARKE.

More than a year ago volume one of the Fifteenth Annual Report of the New York state geologist made its appearance. In the introduction to this report several papers were announced which were not included in the volume, one of them being a monograph of the Dictyospongidae. It is this monograph which has now been published as volume two of the report above mentioned. It also appears in another binding as Memoir II of the New York State Museum. Unfortunately the annual report of the state geologist does not contain the complete monograph, the descriptions and illustrations of Carboniferous species being omitted. This monograph has long been in preparation by Drs. Hall and Clarke, and the printing of it had only been begun at the time of Dr. Hall's death.

The dictyospongidae are an extinct family of hexactinellid sponges, whose nearest living representative is the delicate glass sponge, *Euplectella*, commonly known as the "venus flower basket." They lived in greatest abundance during later Devonian and early Carboniferous time, though their most ancient representatives occur far back in the Silurian. Their fossil remains are especially abundant in the sandstones of the Chemung formation in western New York, several extensive colonies of them having been discovered as they grew upon the ancient sea bottom. Notable collections of them have also been made in the Waverly sandstones in Ohio, and in the Keokuk shale at Crawfordsville, Ind., and from the last locality only, have specimens been found in which the spicular skeleton of the sponge has been preserved.

The variety of forms assumed by these interesting sponges is wonderful, and the earlier observers were at a loss to know where to place them in the zoölogical classification. Before their sponge nature had been definitely established by Whitfield in 1881, they had been described as cephalopods and as marine plants. In life these organisms must have been most beautiful objects, "with their manifold variety of

graceful and striking shapes, they were not the somber bodies we find them to be in the rocks, but formed the most delicately woven fabrics of glass, latticed vases, urns and cups of the rarest delicacy and beauty. They must have been, when denuded of their sarcode, among the most exquisite structures of the past, as their descendants are of the present. Nothing, for example, could have surpassed the graceful filigreed chalice of *Botryodictya ramosa*, with its slender, tufted pedicel expanding above with a cup ornamented with pendant pouches."

In the list of genera and species, twenty-eight genera and one hundred and twenty eight species of these organisms are recognized, a great majority of them being here described for the first time. These descriptions of genera and species, with the introductory portion of the volume, fill two hundred quarto pages of text, and they are illustrated by seventy finely executed lithographic plates.

S. W.

Geological Report on Isle Royale, Michigan. By ALFRED C. LANE. Geological Survey of Michigan, Vol. VI, Part I. Lansing, 1898, pp. i + 281. 16 plates, 29 figures, 13 tables.

The report begins with a historical sketch of the mining operations from pre-historic times to the present. This is followed by a description of the method of constructing cross sections of the country from drill records, and this by an account of the succession of rocks forming the island, involving a detailed statement of the rocks traversed by sixteen drill holes. The results are compared with Irving's cross sections of Keweenaw Point, and the conclusion reached that there is represented on the Isle Royale practically the whole of the copper range as it exists from the Central mine to Portage Lake. A comparison is made with the Minnesota section with less definite results.

The portion of the report of more general interest is that which treats of the grain of rocks, both the theoretical discussion and the application of the theory to the rocks under investigation. The discussion opens with the consideration of conditions that affect cooling of molten magmas. Laws controlling the loss of heat are expressed mathematically, and diagrams are constructed exhibiting rates of cooling under various conditions. Deductions regarding the variations

in the grain of rocks corresponding to these conditions are exceedingly important and interesting. Some of the theoretical deductions are as follows : (1) After the temperature at the center of an intruded magma has fallen about one fourth of the interval between the initial temperature and the marginal temperature, the rate of cooling at a given temperature is the same for all parts of the sheet. (2) If the initial temperature (of intrusion) and conditions of cooling are such that a considerable time elapses before any part of the sheet reaches the point of solidification, the rate of cooling will be the same at all points, and, so far as the grain is dependent on it, there will be no change of grain, but the grain will be uniform from margin to center. (3) The hotter the dike or sheet initially, the less will be the width of the marginal zones of gradually finer grain ; also, the hotter the country rock, the less pronounced will be the marginal zone of finer grain. (4) The time of cooling varies as the square of the thickness of the dike or sheet, so that a dike 200 feet thick will cool four times as slowly, other things being equal, as a dike 100 feet thick. (5) Before the center (of an intruded mass) begins to cool off, the time required for a given loss of temperature for any point will vary as the square of its distance from the margin.

In applying the theory to the rocks examined it was found that some minerals, such as augite and feldspar, conformed fairly with theoretical requirements. In the case of sheets which have solidified before the center had appreciably cooled, it was found that "the area of cross sections or surface of the grains varies directly as the slowness of cooling." Again, " the linear dimensions of the augite patches (in the ophites, are directly as the distance from the margin."

With regard to the effect of chemical composition on grain, it is announced that " other things being equal, the greater the abundance of its constituent molecules, the coarser the grain of any mineral."

In conclusion, Dr. Lane ventures the prophecy "that it will prove widely true that superficial (extrusive) basic rocks are characterized by an increase of grain to near the center, while deep-seated basic rocks have a broad central zone of nearly uniform grain." He remarks in connection with the question of the effect of geological environment upon rocks that "it must also be remembered that the possession and loss of gas by diffusion follow the same laws as the possession and loss of the imponderable 'caloric,' while the possession of gas may greatly lower the temperature of solidification as glass."

The report closes with chapters on the petrography of the rocks; on the topography and Quaternary geology; the stratigraphy; and the chemical problems which are treated briefly. The last chapter is devoted to diabases, probably Keweenawan, intrusive in the Huronian. Among various interesting observations made in connection with these rocks is the conclusion that the micropegmatitic (micographic) intergrowth of quartz and feldspar found in some of them is undoubtedly a primary cystallization, and not a result of alteration in the rock.

J. P. I.

The Department of Geology and Natural Resources of Indiana. Twenty-third Annual Report. By George H. Ashley, Ph.D., Assistant State Geologist.

The report consists of 1741 pages, the first 1573 of which are devoted to the coals and coal area of the state. The state geologist, Mr. W S. Blatchley, is to be congratulated on having secured, for this work of such importance to the state, the services of so painstaking and energetic a worker as Dr. Ashley.

The primary idea of the author seems to ,have been to make the report of the greatest possible value to those interested in the coal industry. Nevertheless it discloses much that is new concerning the structure of the southwestern part of the state, and throws light on the physical conditions that attended the formation of the Coal Measures of the eastern interior coal field.

Instead of using the letters of the alphabet to designate the different coal beds, as is done by Mr. Cox in the Seventh Annual Report, or Arabic numerals, as was done in the Illinois and Kentucky reports, the author has made use of Roman numerals, each of which denotes a division of the Coal Measures. There are eight of these divisions, numbered from below upward. In those localities, where a division includes more than one coal bed, the small letters of the alphabet are brought into use. For example, the three coals of Division v are designated v, va, vb. This method seems to present the advantage of at all times denoting the exact horizon under consideration, and of locating the beds of small area.

The organization of the volume divides it into four parts. Part I dealing with the Geology of Coal; Part II, with the General Geology

of the Coal Measures of Indiana; Part III, with the Detailed Geology of the Indiana Coal Field; and Part IV, with Mines, Mining, and the Utilization of Coal. In Part III the method of treatment is by counties.

Probably the best feature of the report is to be found in the excellent illustrations, which consist of 986 figures, 91 plates, and 7 maps. Especially are the maps and the accompanying sections to be commended.

The latter part of the volume is devoted to reports of the inspector of mines and the natural gas supervisor.

A. H. PURDUE.

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United States Geological Survey. Monograph XXXI. Geology of the Aspen Mining District, Colorado, with Atlas. JOSIAH EDWARD SPURR. Samuel Franklin Emmons, geologist in charge.

The monograph is primarily concerned with the economic interests of the Aspen district. But it also contains much that is of general scientific interest. Mr. Emmons contributes the introduction, but the body of the monograph is the work of Mr. Spurr. The volume is profusely illustrated and the accompanying atlas contains sheets giving the general geology and topography of the district, besides eight special sheets giving the detailed geology of limited areas. It also contains numerous sections constructed on an elaborate scale, which make the complex faulting intelligible. Both the monograph and its accompanying atlas exemplify the magnificent execution characteristic of the United States Geological Survey.

Great interest attaches to the author's study of faults as set forth in this work. Aspen seems to have furnished a field quite worthy of his best endeavor. Some of the sheets presented in the atlas seem like inextricable puzzles; but this special student of faults straightens out the "crazy-work" in an admirable way and makes it all intelligible. It is of interest to note the fact that movement along some of the faulting plains is taking place at the present time at a rate which requires recognition in the practical operations of mining.

Under "Chemical Geology" some observations are given which throw light on the vexed question of dolomization. The origin and change of ores is also discussed.

W. T. LEE.

Geological Survey of Georgia. W. S. Yeates, State Geologist. *Bulletin No. 7, A Preliminary Report on the Artesian-Well System of Georgia.* By S. W. McCALLIE, Assistant Geologist. State Printer, Atlanta, Ga., 1898, pp. 214.

One of the significant signs of growing wisdom in the administration of state surveys is the increased attention given to common resources of wide interest as distinguished from rich deposits of immediate value to a fortunate few only. Among these resources of common interest is the water supply which admits of successful treatment on a scientific basis, whether in the form of flowing wells or otherwise. In real importance it transcends many of the more impressive subjects. The present treaties is an excellent expression of this commendable policy. The first thirty pages are devoted to a clear exposition of the essential conditions of successful artesian wells and practical considerations relative to them. This is well illustrated. The rest of the volume is devoted to the special consideration of the artesian wells of Georgia, in which much data of general geological interest is incidentally included. Large artesian resourses are shown. While full data are not obtainable, it is clear that notable improvement in public health has resulted from the use of these wells. T. C. C.

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SIR WILLIAM DAWSON.

In Sir William Dawson there has passed away the last survivor of that distinguished group of naturalists which in the arlier part of this century achieved for science in America such rilliant results and such widespread recognition—men whose ange of knowledge was almost encyclopedic, and many of 'hom made valuable contributions to science in widely separated elds. The environment of the man of science has now changed, nd the older type of naturalist seems unfortunately about to lisappear.

Sir John William Dawson was from near Nova Scotia, a province which has produced more than its share of the Canalians who have risen to eminence in the various walks of life, aving been born at Pictou on October 13, 1820. He died at Montreal on November 19, 1899, at the age of 79.

His father, James Dawson, was from near Aberdeen, Scotand, and came to Nova Scotia to fill a position in a leading usiness house in Pictou, and on the termination of his engageient began business there as a shipbuilder on his own account.

While still at school in Pictou, at the age of 12, he developed love for natural science, inherited from his father, and made arge collections of fossil plants from the Nova Scotia Coal Measures, so well exposed about his native place. He speaks of

[illegible]

[illegible]

therefore not strictly like, still suggests the probability of the Stigmaria having grown in slush in like manner." And in another part of the same letter, referring to the now celebrated Joggins section on the coast of Nova Scotia, he says: "Dawson and I set to work and measured, foot by foot, many hundred yards of the cliffs, where forests of erect trees and calamites most abound. It was hard work, as the wind one day was stormy and we had to look sharp lest the rocking of living trees, just ready to fall from the top of the undermined cliff, should cause some of the old fossil ones to come down upon us by the run. But I never enjoyed the reading of a marvelous chapter of the big volume more. We missed a botanical aid-de-camp much when we came to the tops and bottoms of calamites and all sorts of strange pranks which some of the compressed trees played."

About this time the governing body of McGill College at Montreal was looking about for some one fitted to assume the principalship of the institution and to reorganize it.

The college, founded by Royal Charter in 1821, had made but slow progress in its earlier years, and was at this time, through litigation and other causes, almost in a state of collapse. Sir William, then Mr. Dawson, was pointed out to the Governors of the College by Sir Edmund Head, then Governor General of Canada, as a man who, if his services could be secured, was eminently fitted to undertake the task of reconstructing the university. In the meantime, ignorant of all this, he was prosecuting a candidature for the chair of Natural History in his alma mater, the University of Edinburgh, rendered vacant by the death of Professor Edward Forbes, and in which he was strongly supported by the leading geologists of the time. By a strange coincidence, just as he was about to leave Halifax for England in connection with this candidature, intelligence arrived that the Edinburgh chair had been filled at an earlier date than his friends had anticipated, and at the same time a letter was received offering him the principalship of McGill.

The services of Dr. Dawson were accordingly secured, and in 1855 he assumed the principalship of McGill College, stipulating

at the same time that the chair of Natural History should be assigned to him. In his inaugural discourse he said: "At a time when literary and scientific pursuits are so widely ramified everyone who aims to do anything well must have his special field of activity. Mine has been the study of nature, especially in those bygone aspects which it is the province of geology to investigate. My only other special qualification for my present position depends on the circumstance that the wants of my native province have induced me to devote much time to inquiries and pursuits relating to popular education. I come to you, therefore, as a naturalist and an educationalist, trusting that I may be enabled in these capacities to render myself useful, and asking for my youth and present inexperience in the affairs of this institution your kind indulgence, and for the work in which I shall be engaged your zealous coöperation."

The University as he found it had three faculties and but sixteen professors, a number of whom gave only a portion of their time to university work, while the buildings and equipment were wretched. When it is stated that the University has now 120 professors and instructors of various grades and an equipment which is in all departments fairly good, and, in some of them, unsurpassed, some idea may be gained of the progress which the institution made under Sir William Dawson's care and guidance.

As a professor of natural science Sir William at this time delivered courses in chemistry, botany, zoölogy, and geology, and natural science became a very favorite study among the students, for he was an excellent lecturer, and his enthusiasm for these studies was communicated to all who heard him. As years went on, the instruction in the first three of these subjects was undertaken by others, and a special chair of Geology and Paleontology was endowed by his old friend and co-worker, Sir William Logan, a chair which he held until his final retirement. His teaching work, however, formed but a small part of his daily labors. In addition to administering the affairs of the University he was first and foremost in every movement to

further education in the province, and no educational board was complete without him. He was the honorary president of the Natural History Society and never missed a meeting or a field day, and also identified himself closely with many other societies in Montreal, and spared neither time nor labor on their behalf.

Over and above all this he found time to carry out original work along several lines, achieving most valuable results, as well as to write many popular works on science, more especially in its relation to religion. Original investigation he always considered to be one of the chief duties and pleasures of a man of science. Most of his work along these lines was done during his summer vacations; in fact he was led to accept the position of principal in McGill chiefly by the fact that the vacations gave him leisure and opportunity for work of this kind.

He was always very progressive in his ideas relative to the scope and development of university teaching, and was continually urging the endowment of new chairs and the broadening of university work, so that all young men wishing to train themselves for the higher walks of life might in the university find their needs supplied. As an instance of this it may be mentioned that so far back as 1858 he succeeded in establishing a school of civil engineering, which, after a severe struggle for five years, succumbed to some unfriendly legislation, only, however, to be revived by him in 1871 and developed into the present faculty of applied science of McGill University, with its numerous departments, its full staff of instructors and excellent equipment. Sir William, furthermore, never hesitated, if funds were not forthcoming in sufficient amount for these purposes, to subscribe large sums out of his own limited private means, and he was also the continual helper of needy students desiring to avail themselves of the University's teaching.

Sir William received the degree of M.A. from the University of Edinburgh in 1856, and the degree of LL.D. from the same University in 1884. His attainments and the value of his contributions to science were widely recognized, and he was elected

an honorary or corresponding member of many learned societies on both sides of the Atlantic. He was made a Fellow of the Geological Society of London in 1854 and of the Royal Society in 1862. In 1882 he was invited by Lord Lorne to aid in the organization of the Royal Society of Canada as its first president. He was also President of the Geological Society of America and of both the American and British Associations for the Advancement of Science. In 1884 he received the honor of knighthood.

After a long life of continuous labor, Sir William's health, in 1892, became seriously impaired, and it became necessary for him to lay aside his work for a time and spend a winter in the South. Failing to recover his strength, however, he resigned his position as principal in June 1893, and retired from active work. During the later years of his life his strength gradually ebbed away, and what little work he could undertake consisted in arranging his collections and working up some unfinished papers. Several of these were published in 1894 and 1895, but the years of quiet labor in his favorite pursuits, to which he looked forward at this time, were cut short by a series of sharp attacks, culminating in partial paralysis, which forbade further effort. During the last few years, from time to time, his strength rallied somewhat and he attempted to resume his work. Only a few days before his death he penned a short essay on the "Gold of Ophir." He passed away on the 19th of last month, very peacefully and without pain. We may say, in the words of Dr. Peterson, his successor in the principalship of the University, "For such a painless passing out of life no note of sorrow need be struck. There is no sting in a death like his; the grave is not his conqueror. Rather has death been swallowed up in victory — the victory of a full and complete life, marked by earnest endeavor, untiring industry, continuous devotion and self-sacrifice, together with an abiding and ever-present sense of dependence on the will of heaven. His work was done, to quote the great Puritan's noble line, 'As ever in his great Taskmaster's eye.'"

Lady Dawson, with three sons and two daughters, survive him, of whom the eldest, Dr. George M. Dawson, the present director of the Geological Survey of Canada, has inherited his father's love for geological studies, and has achieved wide distinction in the world of science.

Sir William's first original contribution to science was a paper read before the Wernerian Society of Edinburgh in 1841, on a species of field mouse found in Nova Scotia. From that time onward he was a continuous contributor to scientific journals and to the publications of various learned societies. His papers were very numerous and covered a wide range of subjects in the domain of natural history. No less than 158 titles are recorded under his name in the Royal Society's catalogue; and in a bibliography which he prepared for the Royal Society of Canada in 1895, and which included only books and papers of the first importance, 128 titles are recorded. He contributed over 100 papers to the publications of the Montreal Natural History Society alone. His complete bibliography, now in course of preparation, will certainly include several hundred contributions. The most important work of his earlier years was an extended study of the geology of the maritime provinces of the Dominion of Canada. His results are embodied in his *Acadian Geology*, already mentioned, a volume of nearly 1000 pages, accompanied by a colored geological map of Nova Scotia, which has passed through four editions. In writing to Sir William in 1868, Sir Charles Lyell says of this work: "I have been reading it steadily and with increased pleasure and profit. It is so full of original observation and sound theoretical views that it must, I think, make its way, and will certainly be highly prized by the more advanced scientific readers." It is the most complete account which we have of the geology of Nova Scotia, New Brunswick, and Prince Edward's Island, although since it appeared large portions of these provinces have been mapped in detail by the Geological Survey of Canada, and Sir William's conclusions modified in some particulars. In carrying out this work Sir William paid especial attention to the paleontology of the

Carboniferous system, and to the whole question of the nature and mode of accumulation of coal. He subsequently studied the paleontology of the Devonian and Upper Silurian systems of Canada, discovering many new and important forms of plant life. In 1884 he began the study of the Cretaceous and Tertiary fossil plants of western Canada, and published the first of a series of papers on the successive floras from the lower Cretaceous onwards, which appeared in the *Transactions of the Royal Society of Canada*. He also contributed a volume entitled *The Geological History of Plants* to Appleton's International Scientific Series. In 1863 he published his *Air Breathers of the Coal Period*, in which were collected the results of many years' study in the fossil batrachians and the land animals of the Coal Measures of Nova Scotia. The earliest known remains of microsauria were then discovered by him in the interior of decayed tree stumps in the Coal Measures of South Joggins. The results of his later studies in these creatures were embodied in a series of subsequent papers which appeared from time to time.

On taking up his residence in Montreal his attention was attracted by the remarkable development of Pleistocene deposits exposed in the vicinity of the city, and he undertook a detailed study of them, and especially of the remarkably rich fossil fauna which they contain. He also studied subsequently the Pleistocene deposits of the lower St. Lawrence, and instituted comparisons between them and the present fauna of the Gulf of St. Lawrence and of the Labrador coast. The results of these studies appeared in a series of papers as the work progressed, and were finally embodied in a volume entitled *The Canadian Ice Age*, which was issued in 1893 as one of the publications of the Peter Redpath Museum of McGill University. This is one of the most important contributions to the paleontology of the Pleistocene which has hitherto appeared.

Sir William's name is also associated with the renowned Eozoon Canadense, discovered by the Geological Survey of Canada in the Grenville limestones of the Canadian Laurentian, and described by him in 1864 as a gigantic foraminifer.

Concerning this remarkable object there has been a widespread controversy and a great divergence of opinion. Some of the most experienced observers in the lower forms of life, such as Carpenter, accepted it as of organic origin, while others considered it to be inorganic, and while the balance of opinion now possibly favors the latter view, its resemblance microscopically to certain organic forms is certainly most remarkable. The literature of this subject, which includes many papers by Sir William, is quite voluminous, but the chief facts are summed up in his book, entitled *The Dawn of Life*, which appeared in 1875.

Sir William was also a prolific writer of popular works on various geological topics. Among these may be mentioned *Fossil Men and Their Modern Representatives*, *The Chain of Life in Geological Time*, *Egypt and Syria their Geology and Physical Geography in Bible History*, *Modern Science in Bible Lands*, *Modern Ideas of Evolution*, *Salient Points in the Science of the Earth*, *Eden Lost and Won*, and *Relics of Primeval Life*. As may be inferred from their titles, many of these books display a strong theological bias. Sir William was a Presbyterian of the old school and strongly opposed to all theories of the evolution of man from brute ancestors, nor would he allow anything more than a very moderate antiquity for the species. He held that there is no adequate reason for attributing the so-called "Neolithic" man to any time older than that of the early eastern empires, while he thought the time for Paleolithic man need not be more than twenty or thirty centuries in addition, man having thus made an abrupt appearance in full perfection not more than, say, six or eight thousand years ago.

These works on the relation of science and religion met a popular need and were of great comfort to many a pious soul, who feared that the whole framework of faith was being swept away by the advancement of science. Their value, however, was not permanent, and they are not the works by which Sir William Dawson will be remembered. His reputation is founded on the great contributions to our permanent stock of knowledge which he has made and which are embodied in his works on pure

science, representing achievements of which any man might well be proud.

Sir William had a courteous, or rather a courtly, manner, based on a genuine consideration for all. He was respected and beloved by all who knew him, and especially endeared himself to all who studied under him. The preëminent note of his character was simplicity and singleness of purpose. His loss will be felt especially in the institution with which he was long connected, but his name has been perpetuated in connection with the geological department of his university by the establishment of a second chair in geology, to be known as the Dawson Chair, which has just been endowed in his memory by Sir William Macdonald.

FRANK D. ADAMS.

₹ANITE ROCKS OF BUTTE, MONT., AND VICINITY[1]

IN the western mountainous part of Montana there are sev-
.l extensive areas of granitic rocks, which are commonly sur-
ınded by sedimentary beds and in part covered by later
.canic rocks. The largest of these granite masses forms a
›untainous area having no commanding summits, but consti-
ing the continental water parting separating the waters of the
lantic from those tributary to the Pacific Ocean. This district
.argely drained by the Boulder River, and as the mountains
ve no other name, they too are sometimes called by this name,
which reason it will be used to designate the intrusive mass of
ınite itself. Unmistakable evidences of intrusion are common
ɔut its borders, and as the rock cuts and metamorphoses fos-
ferous Carboniferous rocks and what are believed to be Creta-
ɔus rocks as well, and is overlaid by Neocene sediments, its
ɛ is known within these limits.

The Boulder batholith is a body of granitic rock, in part cov-
:d by later lavas, but continuously exposed from the Highland
ɔuntains (sixteen miles south of Butte) to the vicinity of
:lena, a distance of fifty miles in a north and south direction
d twenty-four miles from east to west. The intrusive nature
the mass is very strikingly shown at the northern and southern
ıits, and also at Elkhorn on the east. At these places the
ınitic rocks have produced very marked contact metamorphism,
d cut across the ends of the upturned sedimentary series.
:ar its border the granite also includes in its mass fragments of
: other rocks. There is no suggestion of a laccolithic uplift-
;, for although near Helena, and probably elsewhere, the
ınitic rocks extend outward under the sedimentary rocks, and
: latter in certain places form a thin cover over the intrusion,
t the strata dip toward the intrusion conformable to a great
:iclinal uplift wholly independent of the batholith.

[1] Published by permission of the Director of the U. S. Geological Survey.

The rocks of this batholith present a wide variation in mineral and chemical composition, but a study of the field relations shows they must be regarded not only as facies of the same magma, but as parts of one mass. The very basic rocks all occur at the margins, yet there are variations within the main body itself which are clearly recognizable rock types, yet cannot be discriminated in mapping. This difficulty has been experienced by those geologists working in the Sierra Nevada, where, as stated by Turner,[1] a considerable variety of rock-types have been mapped as granodiorite, "although, as a rule, gabbro, even when genetically related to granodiorite proper, has been separated." Where detailed mapping upon a large scale map is not possible, this difficulty of separating parts of a single intrusive body in which the rock-types grade into one another can only be met by an arbitrary use of the name of the prevailing rock-type for the entire mass, as has commonly been done heretofore, or by using a generic term like granolite[2] to embrace all coarsely granular rocks.

The prevailing rock of the batholith is a granite whose composition is that given under the number 518. It is a normal hornblende-granite which is very generally sheeted, forming picturesque crags and bowlder groupings. It disintegrates readily into platy masses or shells which separate from the bowlders and themselves crumble to a coarse sand. Over large tracts disintegration has reduced the rock to a smoothly rolling surface, on which scattered bowlders rise above the general level. Perfectly fresh material can, therefore, be obtained only when the rock has been quarried or exposed by mining operations. It is a medium to coarse-grained rock, the average size of the grain being 3–5 mm. The grayish quartz and white feldspar grains are of about equal size. Black mica and dark green hornblende are present in considerable quantity. Under the microscope it shows the normal characters of a granite, but contains an unusual amount of plagioclase.

[1] H. W. TURNER: Granitic rocks of Sierra Nevada, JOUR. GEOL., Vol. VI, 1899, p. 146.

[2] See TURNER: loc. cit., p. 141.

In the following table the results are given of the analyses so ar made of the rocks of the Boulder batholith:

NALYSES OF ROCKS FROM THE POST-CRETACEOUS GRANITIC BATHOLITH OF THE BOULDER MOUNTAINS, MONTANA

				Butte granite						Aplites	
	526	525	130	311	623	6	989	98	518	640	951
'$_2$	49.22	56.41	61.64	63.87	63.88	64.05	64.34	64.17	67.12	76.87	77.05
$_2$	0.95	0.68	.71	.65	.65	.60	.53	.67	.48	.11	.12
O_3	12.02	17.62	15.63	15.39	15.84	15.38	15.72	15.25	15.00	12.52	12.84
O_3	2.77	1.24	3.39	1.93	2.11	2.20	1.62	2.16	1.62	0.67	.56
O	8.80	3.55	2.69	3.08	2.59	2.74	2.94	2.98	2.23	none	.14
O	tr	.08	.04	.11	.07	.11	.12	.04	.06	...	none
O	10.56	8.66	4.90	4.30	3.97	4.30	4.24	4.24	3.43	0.49	.57
O	9.29	3.97	2.82	2.23	2.13	2.08	2.17	2.60	1.74	0.09	tr
O	1.70	2.61	3.72	4.18	4.23	4.00	4.04	4.34	4.52	5.78	5.52
O	1.90	3.35	2.64	2.76	2.81	2.74	2.76	2.62	2.76	2.47	2.81
O below 110°	0.27	.14	.28	.19	.22	.27	.25	.16	.09	0.25	.22
O above 110°	1.63	.76	.91	.69	.66	.83	.76	.65	.58	0.52	.48
O	.03	.09	.08	.07	.09	.08	.06	.07	.07	...	none
)	.03	.08	.04	.04	.02	.04	.03	tr	.03	...	none
O_5	0.43	.49	.21	.17	.21	.21	.14	.16	.15	.05	none
	.08	.07	...	...	...	...	...	tr	...	...	...
	.05	...	...	.07	...	.07	.03	...	...	...	none
$_2$	.04	...	none	...	...	...	...	.07	tr	...	...
$_2$	...	...	none	.15	...	.35	.03	none	none	...	none
Totals	99.77	99.70	99.70	99.91	99.72	100.05	99.80	100.18	99.88	99.82	100.31

H. N. Stokes, Analyst.

526, 525. Contact facies of granite mass, Red Mountains.

130. Diorite, Red Rock Creek, intrusive in batholith.

311, 623, 6, 989. Butte type of granite, Butte district.

98. Head of Clancey Creek, northern part of batholith.

518. Prevailing type of granite of batholith, Boulder.

640, 951. Aplites of Butte granite, Butte.

The following table shows the chemical composition of this ock, only the essential elements being given, the complete analyis being shown in the preceding table. Partial analyses of quartznonzonite from the Sierra Nevada[1] and of Brögger's adamellite[2] re given for comparison.

[1] H. W. TURNER: The granitic rocks of the Sierra Nevada, JOUR. GEOL., May 1899, p. 141.

[2] Die eruptionsfolge der triadischer Eruptivgesteine bei Predazzo, p. 62.

	Boulder Granite	Quartz Monzonite	Granodiorite	Adamellite
		2179 Sierra Nevada	Pyramid Peak	Landsberg bei Barr Vogesen Rosenbusch
SiO_2	67.12	66.83	67.45	68.97
Al_2O_3	15.	15.24	15.51	14.80
CaO	3.43	3.59	3.60	3.82
MgO	1.74	1.63	1.10	1.15
K_2O	4.52	4.46	3.66	4.53
Na_2O	2.76	3.10	3.47	2.40

The close similarity of this rock to the quartz-monzonites of the Sierra Nevada is apparent from these figures. It is evident from the analyses that the Boulder granite nearly corresponds to Brögger's adamellite.

THE BUTTE GRANITE

The Butte granite (or quartz-monzonite) covers an area of several square miles and is the prevailing rock of the Butte district, and the one in which the world-famous copper and silver veins of that place occur. It is, therefore, of more than ordinary interest, and has been carefully investigated in connection with the study made of the general and economic geology of the district. It is a rather dark colored, coarsely granular rock which is seldom seen in conspicuous exposures about the productive mines owing to a close sheeting with much decomposition near the mineral veins and ready disintegration in other parts of the district. Away from the mineralized areas it is well sheeted and forms the usual bowlder and castellated forms of such rocks. Its darker tone and greenish feldspars render it easily distinguished from the bowlder type. Throughout the entire district it is very uniform in appearance, as it proves upon analysis to be in composition, though differing somewhat in the relative proportions of the constituent minerals. It is also uniform in grain over the entire district, but hand specimens show in local patches a variation of textures. Inclusions of a much darker and finer-grained dioritic rock are often seen weathered in relief on exposed surfaces; they are always small, seldom over a few inches across, angular and rather scarce, never making an appreciable part of

the mass. Owing to disintegration prefectly fresh specimens can only be obtained from surface quarries or underground workings. The exact relations of this mass to the general area were not satisfactorily determined, though it appears certain from the exposures that it is an integral part of the batholith and not a separate intrusion. At several localities a sharp gradation was observed, with narrow transition bands between the lighter colored granite with its white feldspars and the darker Butte type.

Orthoclase is an abundant and usually a readily recognizable constituent as its pinkish color is in contrast to the green tones of the plagioclase, and it has, moreover, a tendency to develop in relatively large crystals which give the rock a somewhat porphyritic look. Plagioclase, black hornblende, black biotite, and quartz are easily distinguished by the eye. Under the microscope the rock is seen to vary between a rather basic hornblende-granitite and a quartz-diorite. There is usually a slight amount of chlorite present, but the biotite and hornblende are as a rule fresh. Titanite, apatite, iron ore, and zircon are present as accessories. It will be seen that the rock is only a somewhat more basic phase of the granite of the region, and that it closely resembles granodiorite, though in the Butte rock the plagioclase is more basic, being a sodic labradorite. The four analyses given in the general table show the rock to be remarkably uniform in chemical composition over the entire area.

The following table gives partial analyses of the Butte granite and of the related rocks from other localities :

PARTIAL ANALYSES OF BUTTE GRANITE AND RELATED ROCKS

	Butte (average)		Granodiorite (average)	Boise	Banatite (average)		Boulder
SiO_2	64.03		65.48	65.25	64.39		67.12
Al_2O_3	15.58		16.05	16.94	15.90		15.
Fe_2O_3	1.96		1.47	1.60	5.63		1.62
FeO	2.83		3.02	1.91			2.23
CaO	4.20		4.80	3.85	4.15		3.43
MgO	2.15		2.13	1.31	1.93		1.74
K_2O	4.11	6.87	2.43	3.02	3.57	7.05	4.52
Na_2O	2.76		3.49	3.57	3.49		2.76

The analysis of the Butte rock is the mean of the four analyses already given. The granodiorite is the mean of five analyses given by Turner.[1] The Boise rock is described by Lindgren.[2] The Banatite is a mean of the analyses quoted by Brögger.[3] From the analyses it will be seen that the rock closely resembles a banatite in composition; the lime and sum total of the alkalis being the same, but in the Butte rock the potash exceeds the soda in amount. It also resembles the granodiorites, but the alkalies present an inverse ratio.

In order to furnish a basis for calculating the mineral composition of this rock, fresh rock was crushed, the hornblende and biotite separated by Dr. H. N. Stokes by the use of Thoulet solution, and these two minerals from each other by sliding on paper. The resulting material was examined under the microscope and found to be quite pure.

The biotite is quite black in color to the eye, but dark brown under the microscope showing very marked pleochroism. This biotite is characteristic not only of the Butte granite but of the Boulder granite as well. In many sections examined it appear the same in color and pleochroism not only for the Butte roc but for the normal granite of the batholith, and it may b assumed to be the same for both these rocks. The microscopi examination of the biotite material showed a little apatite pres ent, a very little chlorite, and very little hornblende, but thes impurities form a very minute part of the whole. The amphibol is also characteristic of both the Butte granite and the norma granite of the region. It is black or very dark green when see with a hand lens, but pleochroic in dark green tints with larg extinction angle when seen under the microscope. The mate rial analyzed was very pure.

The following table shows the result of the analyses mad of these minerals. Dr. Stokes was unable to obtain a highe

[1] Loc. cit., p. 150.

[2] Mining Districts of the Idaho Basin and Boise Ridge, Idaho. Eighteenth Ann Rept. Director U. S. G. S. 1898, p. 740.

[3] Loc. cit., p. 62.

ıation in the analyses made of each, and the amount of rial available being exhausted further work could not be . For reference the analyses published by Turner of the e and amphibole from the quartz-monzonite of the Sierra da, are also given.[1] The close resemblance of the analyses ›th rocks and minerals to those of the Butte material will ›ted.

	Biotite		Hornblende		Butte granite
	Butte	S N 2652	Butte	S N 2652	
....	35.79	35.75	45.73	47.49	64.03
....	3.51	3.16	1.43	1.21	.60
....	.10	.03	.28	.06	.18
....	.76	.17	....	....	......
....	.20	....	....	....	......
....	13.70	14.70	6.77	7.07	15.58
....	5.22	4.65	4.94	4.88	1.96
....	13.72	14.08	10.30	10.69	2.83
....	.19	.45	.54	.51	.11
....	.13	....	none	....	.07
....	none	.12	none	....	.04
....	.05	.17	11.25	11.92	4.20
....	12.13	12.37	12.32	13.06	2.15
....	9.09	9.19	1.22*	.49	4.11
....	.15	.32	.77	.75	2.76
....	tr	tr	tr	tr	......
:low 110°	1.21	1.03	.49	....	.20
›ove 110°	3.64	3.64	2.29	1.86	.73
tal	99.59	100.00	98.77	100.03	99.87
for F & Cl........	.37		.12		
	99.22		98.65		
	Stokes	Hillebrand	Stokes	Hillebrand	Stokes

ıe Butte analyses are incomplete as the amount of material was too small for work.

he phosphoric pentoxide (P_2O_5) in the analyses of both rals and of the rock itself is assumed to be present as apatite vith an appropriate amount of lime is deducted from the 'ses. The water below 110° C. is assumed to be accidental is also deducted. The analyses are then reduced to 100, he molecular ratios calculated.

[1] Some rock forming biotites and amphiboles. A. J. Sci. Vol. VII, 1899, p. 294.

All the soda is calculated as albite. Microscopic examination shows the plagioclase to be a calcic andesine Ab_1, An_1, and an estimate being made of the proportion of hornblende present, an equivalent amount of lime is deducted and the remainder calculated with the albite molecule to form plagioclase.

The result gives the following composition for the rock:

	I	II
Quartz	23.70	20.8
Orthoclase	19.88	18.
Albite	22.98	28.
Anorthite	11.48	12.1
Hornblende	15.26	16.6
Biotite	4.22	—
Magnetite	1.18	1.5
Titanite	.97	1.4
Apatite	.33	.3
	100.00	98.7

This adds up to 1.51 molecular weight against 1.50 for the bulk analysis of the rock, showing a very close agreement. As the microscope shows the plagioclase to be andesine of about the composition of Ab_1, An_1 (or Sodic labradorite), and albite is not seen in the section, the orthoclase must contain the albite molecule. In the second column the percentages given are those calculated by Lindgren[1] for the granodiorite of Grass Valley—a rock whose chemical analysis, as already shown, closely resembles that of the Butte granite.

The rocks in the vicinity of the Frohner mine are identical in composition with the Butte granite, as shown by the analysis. The region is about thirty miles north of Butte, and the rock part of the general granite batholith.

THE BLUEBIRD APLITE

Associated with the Butte granite there is an unusual development of aplite. So far as known to the writer it is the most extensive occurrence of a granite aplite yet discovered. The

[1] Gold Quartz Veins of Grass Valley, Cal., Seventeenth Ann. Rep. Dir. U. S. Geol. Surv., p. 42.

largest mass is 1¼ miles by $2\frac{1}{16}$ miles, and is known from mine workings to be several hundred feet thick, resting on the Butte granite. Besides this large mass there is another of about one-third the size and numerous smaller bodies, as outlined by the author on the geologic map of the Butte district. In the cases hitherto observed by the writer, and those commonly described, aplites occur in dikes commonly quite narrow, but often of considerable length; such masses have been supposed to be the filling of cracks formed in the cooling granite, the aplite magma coming either from an acid residuum or nucleus of the mass or, as suggested by Turner, a product squeezed out of the crystallizing granite and gathered in cracks due to its shrinkage. A study of the Butte aplites shows that, though the dikes of this material may owe their origin to some such cause, that the irregular lense-like or meniscoid masses are sometimes local bodies unconnected with any feeder. The inference derived from a careful examination of many exposures is that the material is due to some such process as that suggested by Turner—a sort of segregation. In the description of the remarkable differentiation zone of Square Butte[1] it was shown that the basic outer part of the intrusion, itself a product of differentiation, holds a thin band of white syenite due to further separation or differentiation of the feldspathic constituents in the crystallizing mass.

This hypothesis, my belief in which has been strengthened by further observations of other laccoliths in the same region, seems to explain the manner of occurrence of the aplites in the Butte mass. It is believed, upon evidence which cannot be presented here, that the Butte district is on the downthrown side of a fault and that its granitic rocks represent the upper part of the batholitic intrusion. In this uppermost part of the intrusion partial differentiation is believed to have taken place, the normal granite, represented by analysis No. 516, splitting up into the more basic phase represented by the Butte type and the acidic type, the Bluebird aplite. This hypothesis demands that as the Butte granite

[1] WEED and PIRSSON: Highwood Mountains of Montana, Bull. Geol. Soc. Am., p. 406, 1896.

is but slightly more basic than the prevailing form, the pro
portion of aplite should be small. The field observations sho
a quantitative relation which, as far as it can be estimated, co
firms the view.

This hypothesis implies a gathering of the iron, magnesia
and lime molecules out of the general magma and their conce
tration in the quartz-monzonite, with a separation out of t
aplitic material, richer in alumina, alkalis, and silica which did n
form an inner kernel as it has in laccolithic differentiations, b
local masses in the basic granite. This hypothesis has alrea
been anticipated by Cross in the discussion of evidence of d
ferentiation at Rosita, Colo.[1]

If the Butte granite is a border or upper contact facies
the batholith, this separation may have been induced by conta
cooling. Observations of many of the smaller intrusive stoc
of the Montana mountains and of the contacts of the larg
batholiths show that there is more or less of a mixing of ba
and siliceous materials as if they were stirred together wh
pasty. The rocks grade into one another and there are no sha
contacts.

In the large aplite intrusions there is no sahlband alteratio
The grain continues the same in both rocks, but at a certain li
there is a change in the relative proportions of the minerals.
the smaller bodies and little dikelets the grain of the aplite
finer, though there is no contact band or evidence of chilli
In the Butte area this is uncommon. There is, it is true, a sha
contact between granite and aplite, but there are transition for
and even masses of granite in the larger aplite bodies which
clearly not included fragments but integral parts of the ma
Yet there is commonly a definite separation of the two roc
and it is certain that there has been no mixing of the two ma
rials due to convection or movement before consolidation.

In most of the aplite bodies the grain varies considerably fr
place to place; sometimes the rock becomes a micropegmati

[1] Geology of Silver Cliff and Rosita Hills, Colo., Seventeenth Ann. Rep. Dir. U
Geol. Surv., p. 320.

rely a coarse pegmatite. There is sometimes a banding with ternations of fine and coarse-grained material.

The commonly accepted theory of the origin of aplite is iat it represents the acid remainder in a granite or quartz-orite magma after the more basic elements have crystallized. t a late period, after the main mass of the granitoid rock had ystallized, the aplite is forced up from below and fills previously rmed cracks, which are perhaps the result of cooling. Viewed this light they are genetically related to the more basic ranites with which in the Sierra Nevada they are for the most art directly associated.[1]

The aplite.—The following calculation of the mineral composition of the aplite, column I, is based upon the complete emical analyses given in the table. A little biotite is found in e fresh aplite. This is similar to that of the granite and is pposed to have the same composition, and all the magnesia is cribed to this. This leaves an excess of 0.09 of TiO_2, which calculated as titanite.

	I	II
Quartz	37.70	39.45
Potash feldspar	33.90	29.43
Soda feldspar	23.81	23.03
Lime feldspar	2.45	6.56
Biotite	0.72	.90
Magnetite, etc.	1.20	.58
Titanite	0.22	.18
	100.00	100.00

In column II the mineral compositions of the aplites of the ranodiorite of the Sierra Nevada, given by Turner, are given r comparison.

LAMPROPHYRIC CONTACT FACIES

The first two analyses in the large table represent the compo-tions of two lamprophyric contact facies of the batholith. The ocks probably grade into the granite, though the transition is a

[1] H. W. TURNER: Geology of Sierra Nevada, p. 722.

rapid one. More often such rocks occur as intrusions in the altered sediments about the border of the batholith. The first analysis is that of a rock that might be called a diorite, though it hardly comes under that name. It consists mainly of green hornblende, which is stringy and appears to be derived from augite, and of small zonally built basic plagioclase feldspars and a very little quartz. It is a nearly black, quite coarsely crystalline rock, and is an unusual type. It occurs intrusive in phyllites and schists on the summit of Red Mountain, ten miles south of Butte.

The second analysis is that of a rock fairly typical of the batholith contact at many localities. It is a dark gray granular rock, rather finer grained than the granite into which it can in some places be traced by insensible gradations. It is a very basic diorite which approaches a hornblende-gabbro. The hornblende is quite stringy and of uralitic appearance, pale green passing into deeper green and into colorless forms. Brown biotite is rare. Orthoclase is present in small amount and only in interstices between more idiomorphic plagioclase. The latter shows an extremely fine zonal structure and varies between labradorite and albite, and will perhaps in a majority of cases have an average composition corresponding to andesine. A very little quartz is also present, together with apatite and iron ore as accessories.

The rock grades into one consisting mainly of zonally built basic plagioclase in small idiomorphic crystals, equal in amount to that of the combined dark colored constituents, brown pleochroic biotite and hornblende derived from light colored pyroxene, remnants of which still remain.

For the purpose of determining what changes, if any, are accomplished in the ordinary weathering of the granite, an analysis of a coherent but quite friable rock has been made. The material, which is quite typical of that commonly seen in natural exposures, is rather lighter in color than the perfectly fresh rock and has a clayey odor when moist. The greenish plagioclase and pinkish feldspar has been bleached to a dull white or waxy

tint. In the still more altered rock, and in the sands formed by its crumbling down, the white minerals are stained by iron rust. In the rock analyzed the biotite is partly fresh and unaltered, but many of the grains are dull and lusterless, and others are altered to green chlorite; more rarely the cleavages are coated by iron rust. The hornblende shows the most alteration. Some of the grains are fresh, but most of them show masses of ocher, and are penetrated by films of it along cleavages and the grains all show more or less chlorite as the first stage of alteration. These changes all indicate simple hydration and oxidation of the rock, and should accordingly be revealed in the analysis. The following tables show (I) the average composition of the fresh rock, (II) the composition of the disintegrated material, (III) the percentage of each constituent lost, (IV) the percentage of each constituent gained.

Constituents	I	II		III	IV	Limit of possible error of analysis
Silica	64.03	65.14	+1.01		1.41	.3
Titanic oxide	.60	.59	—0.01			
Alumina	15.58	15.63	+0.05		0.32	
Ferric oxide	1.96	2.37	+0.51			.1
Ferrous oxide	2.83	2.13	—0.70			.15
Manganese oxide	.11	tr.	—0.11	100.	10.	
Lime	4.20	3.62	—0.58	14.09		.1
Magnesia	2.15	1.85	—0.30	14.23		.2
Potash	4.11	4.29	+0.13		4.04	.2
Soda	2.76	2.63	—0.13	9.51		.2
Moisture combined	.73 } .96	.75	+0.02			
Moisture below 110°	.23 }	.37	+0.14			
Baryta	.07	.10	+0.03			
Strontia	.04	tr.	—0.04			
Phosphoric acid	.18	.16	—0.02			
	99.86	99.68				

The fresh rock contained a little Cl, 0.17 per cent., the disintegrated rock none. The fresh rock held 0.06 per cent. S (as pyrite), the altered rock 0.05 per cent. SO_3.

While the changes in the character of the rock are largely physical, and its degeneration, due to the rapid expansion and

contraction to which it is here subjected in the extremes of temperature that are so characteristic of the climate, and the chemical changes made possible because of the opportunity for moisture to penetrate the minute cracks thus formed, yet the chemical changes themselves, slight as they appear to be, aid this degeneration by swelling up as the molecules become oxidized and hydrated.

The analysis shows a remarkably small amount of chemical alteration. It is evident, also, that the process is not the normal one of "weathering," since silica is not lost. The presence of sulphides in the rock itself, the proximity of mineral veins, and the presence of sulphurous fumes in the atmosphere which would, of course, acidulate the rainfall, probably account for this abnormal nature of the weathering. Under such circumstances none of the constituents of the rock are constant, since they are all capable of passing into solution under such conditions. As, however, an increase of silica could not take place, this substance must either decrease in amount, or remain constant, and the analyses can be best compared by assuming it constant.

WALTER HARVEY WEED.

I ATTEMPT TO FRAME A WORKING HYPOTHESIS OF THE CAUSE OF GLACIAL PERIODS ON AN ATMOSPHERIC BASIS.

(Continued)

III.

LOCALIZATION OF GLACIATION.

THE problem of localization is in some sense independent of : fundamental hypothesis offered in this paper, and the sug- stions which follow may be accepted or rejected without rying necessarily an approval or disapproval of the main pothesis.

The remarkable distribution of the great ice-sheets.—The chief iters of the Pleistocene ice-sheet lay on the north-northeastern ins of North America, and on the northwestern quarter of rope. On the northwestern Cordilleras there was also a nota- center, though it does not appear to have equaled the others rank.[1] The north-northeastern American centers are properly arded as chief because the spread of the ice-sheets from them

[1] This statement is perhaps open to some question. It is quite certain from field :rvations that the glaciation of the Cordilleran plateau in the United States and ritish Columbia as far north at least as 51° Lat. was much feebler than that of the sissippi basin at corresponding latitudes and much lower present altitudes. It ns also clear that the ice of the north Cordilleras did not creep out upon the plains n extent at all comparable to the spread of the Scandinavian ice-sheet upon the ns of Europe. Considered from these points of view, and they seem to be the ortant ones, the statement can scarcely be questioned seriously. The evidences glaciation on the mountainous border facing the Pacific from 48° northward are, ever, quite impressive. They find their climax perhaps in the 4000 or 5000 feet of ial débris which Russell reports in the foothills of the St. Elias range. In view his it may perhaps be insisted that the glaciation of this region was excep- ally concentrated on the Pacific border, because of the abrupt rise of the surface the height of the mountains, and that the glacial discharge toward the Pacific also exceptionally effective because the high gradient; so that, taking this nsification into account, the sum total of ice formation and ice action in this region not have been so much inferior to that of the European area as the surface dis- ation might seem to imply.

was much more extensive than from the other centers, and because they were not aided essentially by mountainous points of origin, for neither the Labradorean nor the Keewatin centers appear to have been initiated by mountainous elevations. It was a development of glaciation on plains, or at most on plateaus. This fact renders the American ice-fields conspicuously chief among all that developed in Pleistocene times. The glaciation of Europe was centered upon mountains; and remnants of glaciation still linger on the mountain heights of most of the old glacial fields, giving ground for the belief that the local topographic features were there important factors. The glaciation of northwestern Europe would possibly have been rather scant if it had received no greater topographic aid than was afforded in the Keewatin field, but apparently it would not have been absent.

It has often been remarked that the Pleistocene glaciation was gathered about the north Atlantic, but it can scarcely be too much emphasized that the greatest of the glacial areas, and by far the most phenomenal, because of its plain topography, lies on the *western*, or what we are accustomed to regard as the *windward*, side of the Atlantic.

It is further to be noted, that on the western side of America, the glaciation, though notable, was still seemingly much inferior to that of the great northeastern plains; and this in spite of its mountainous character and its adjacency to the great Pacific Ocean, a topographic and hydrographic conjunction which expresses itself now in the most vigorous glaciation outside of the polar circles.

More or less nearly contemporaneous with the growth of the foregoing great ice-sheets, local glaciation developed on nearly all the mountain heights of the earth, whether in the northern or the southern hemisphere, and whether in high or low latitudes. This seems to imply an intensification of glacial conditions generally, but at the same time to indicate that the great ice-sheets were dependent on some special agency of localization. In saying that these scattered areas of glaciation were approximately

ontemporaneous, no dogmatic assertion is intended relative ɔ the exact contemporaneity of glaciation or to its alternation ı the northern and southern hemispheres, nor respecting the octrine of migration of glaciation in longitude. Observational ata are yet insufficient to decide these questions. It is obvious, owever, that the hypothesis under consideration postulates ssential contemporaneity throughout the globe.

The constructive pole of the winds.—As a possible factor in the ɔcalization of glaciation, I venture to offer the suggestion that he axis of the earth's rotation and the axis of the atmosphere's irculation, constructively interpreted, are not identical. By the onstructive axis of the winds I mean that ideal line about which he general currents of the atmosphere would be found to evolve if all minor movements were eliminated or equated and he aggregate east-west components only were regarded. In ther words, it is suggested that the planetary system of circu-ıtion is obliquely adjusted to the planet. This was first sug-ested to me by a study of the peculiar courses of the arctic :e-drift. The polar ice-bearing currents are regarded by experi-nced arctic navigators as concrete expressions of the average ıovements of the atmosphere. To be sure, the ice-drift is ffected by the ocean currents, but these are also, in the main, ıe results of the average direction and force of the winds, ıough they do not so immediately and definitely express it as the :e-drift, because they are also influenced by more remote agencies.

If the axis of the currently postulated "circumpolar whirl" f the atmosphere coincided with the axis of the earth, and if it 'ere the poleward incurving spiral of the winds that swept the ırface of the polar sea, the average ice-drift should assume, or ɜnd to assume, a corresponding incurving spiral. The ice should rowd in toward the pole and rotate upon itself in a direction pposite to the hands of a watch. If this were true, the current 'hich carried Nansen from east to west should have flowed from 'est to east.

If the axis of the "circumpolar whirl" coincided with the xis of the earth, and it were the *outward-running* spiral that

swept the surface of the sea, the ice-fields should rotate in the opposite direction with a centrifugal tendency which should carry the ice outwards and press it against the adjacent continents and give a voluminous discharge down the north Atlantic. An attempt to drift *toward* the pole in such a system would be an absurdity, and Nansen's feat would be inexplicable.

Observed ice-drift.—Neither of these are the phenomena observed. On the contrary, as now abundantly demonstrated, particularly by the remarkable drifts of the Jeannette and the Fram, the average movement near the coast of northern Asia and Europe is westward and slightly northward. This course is held until Greenland imposes itself as a barrier. The outer margin of the ice flow is then forced southward, but immediately it reaches Cape Farewell it curves closely about the point (at least during the summer months) and flows northward and westward to the vicinity of the arctic circle. It here encounters a new barrier in the islands of the American Arctic Archipelago and again moves southward.

On the north coast of Greenland, so far as known, the ice presses hard upon the land, as though its normal course were southward. It flows persistently into the channel between Greenland and Grinnell Land, and gives rise to that strenuous ice-pack which has again and again been assailed by arctic navigators with such great daring and such little success. The recent adverse experiences of the Windward and the Fram are but a renewed expression of the persistence of this south-southwestward drift of the ice currents.

On the north side of the Arctic Archipelago, west of Greenland, the ice crowds hard against the shore, and has thus far prevented the full penetration of Jones Sound or any of the other straits between the northern range of islands. The blocking of Jones Sound appears to be the result of an eastward as well as southerly crowding of the ice.

Farther to the west, Banks Strait, and McClintock Channel, together, form a continuous and rather broad water way, beginning in longitude 130° west and stretching southeasterly to

ongitude 95° west. This channel is always tightly jammed with ce pressed in from the northwest. So persistent and strenuous is he pressure of this ice-pack that it constitutes an effectual barrier o the northwest passage, and has thus far mocked all attempt to orce it. This implies a definite and persistent movement from he northwest to the southeast.

It appears, then, that from far east of Greenland to the west- rn limits of the northern archipelago there is a definite con- 'ergence of the ice currents toward a point located somewhere ıorth of Hudson Bay, *i. e.*, a point lying to the north of the wo great centers of Pleistocene glaciation, the Labradorean and he Keewatin, and on a meridian that runs between them.

It is interesting to note that the point of convergence lies in he general vicinity of the magnetic pole. and this obviously eads to the further suggestion that there may be some genetic onnection between the two as yet undetermined.

Concurrent in import with this is the fact that on the opposite ide of the north pole the coasts of northern Asia and Europe ecome partially free of ice each season. This, although doubt- ess partly due to the effects of the fresh water borne in by he great rivers of those coasts, is probably none the less an xpression of the fact that the polar ice is not crowded down pon those coasts; for if it were, its great mass would com- letely overwhelm the effects of even the great Siberian rivers. 'his phenomenon, taken in connection with the direct observa- ions of the ice-drift made by De Long, Nansen, and others, eaves little room for doubt that the great polar ice-field drifts way from the Eurasian coast and crowds toward Hudson Bay. 'he meridian of 90° may be taken as rudely representing the xis of this converging ice-drift. It is interesting to note that his same meridian bisects the Mississippi valley and crosses the outhern apex of the great American glacial field.

Distribution of arid zone.—Correlated with this remarkable henomenon is an equally remarkable distribution of the great lesert tracts of the eastern hemisphere. Commencing on the Atlantic coast of Africa between 10° and 30° north latitude, the

arid belt stretches north of east across Afric Mongolia it lies between 30° and 50° north l say, in this stretch of 70° or 80° in longitu 20° in latitude. If now we select the meri or about which the desert area reaches its no and follow this through the pole to a point meridian of 90° west, we are in the vicinity c which the arctic ice-drift seems to concen follow the same meridian southward we rea Mississippi valley where the ice-sheet had its s sion. It is to be noted further that this l with the region where a large percentage of descend from the northwest curve about and courses.

If there were space here to enter into oth tional coincidences of an apparently significa found. (The inference drawn is that the axis whirl, if indeed the polar movement can be c coincident with the axis of the earth, but southward from it in the vicinity of the me longitude and 20° more or less distant from

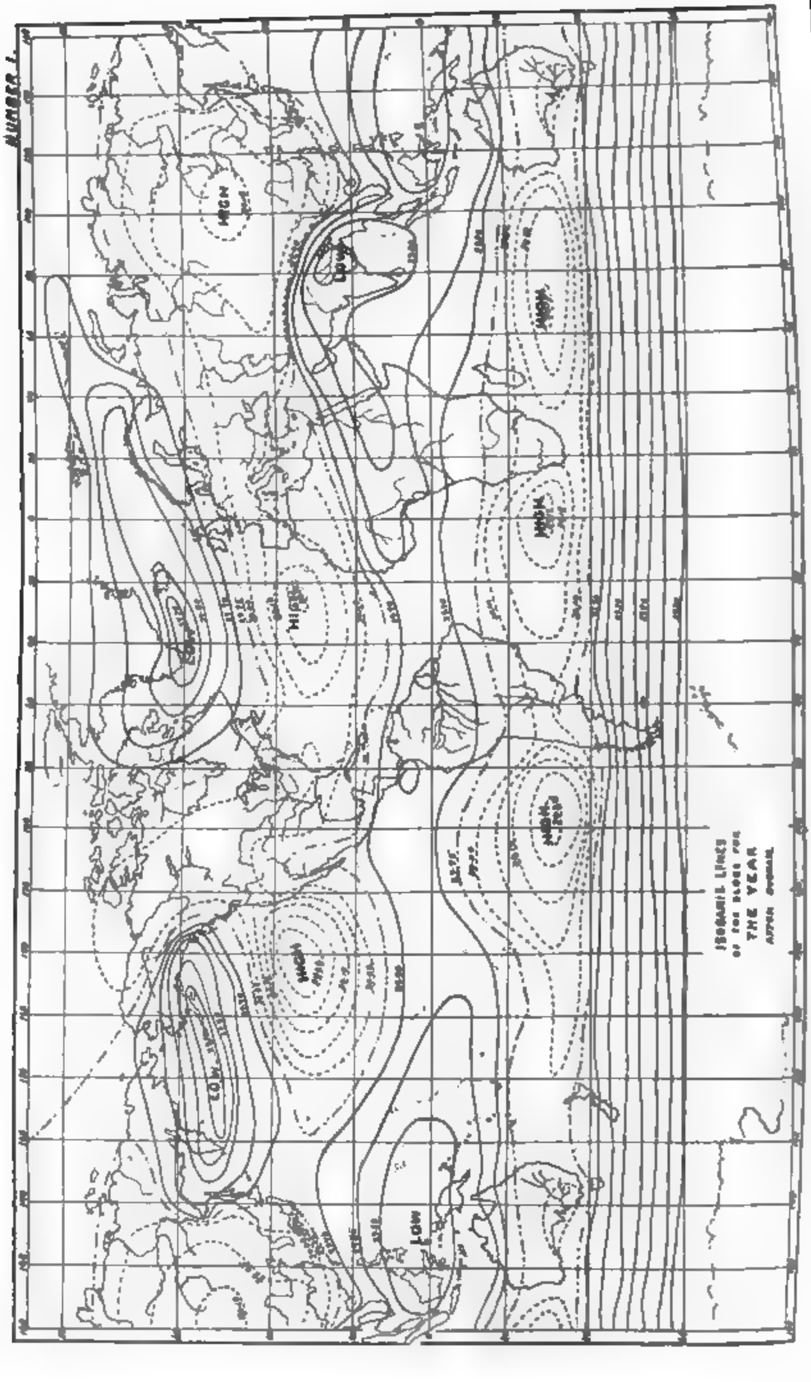
Indications of meteorological data.—As jus entertained is not that there is a simple pol is located here, but that the rather complex polar atmosphere, when combined and corre retical or constructive pole in this region. this will appear more specifically from a stu meteorological data. Unfortunately these a fect and partially uncorrelated, and hence I dence to the natural correlation expressed in International Circumpolar Commission has and discussed its data. It may therefore be have recourse to Buchan's[1] or Hann's[2] mete

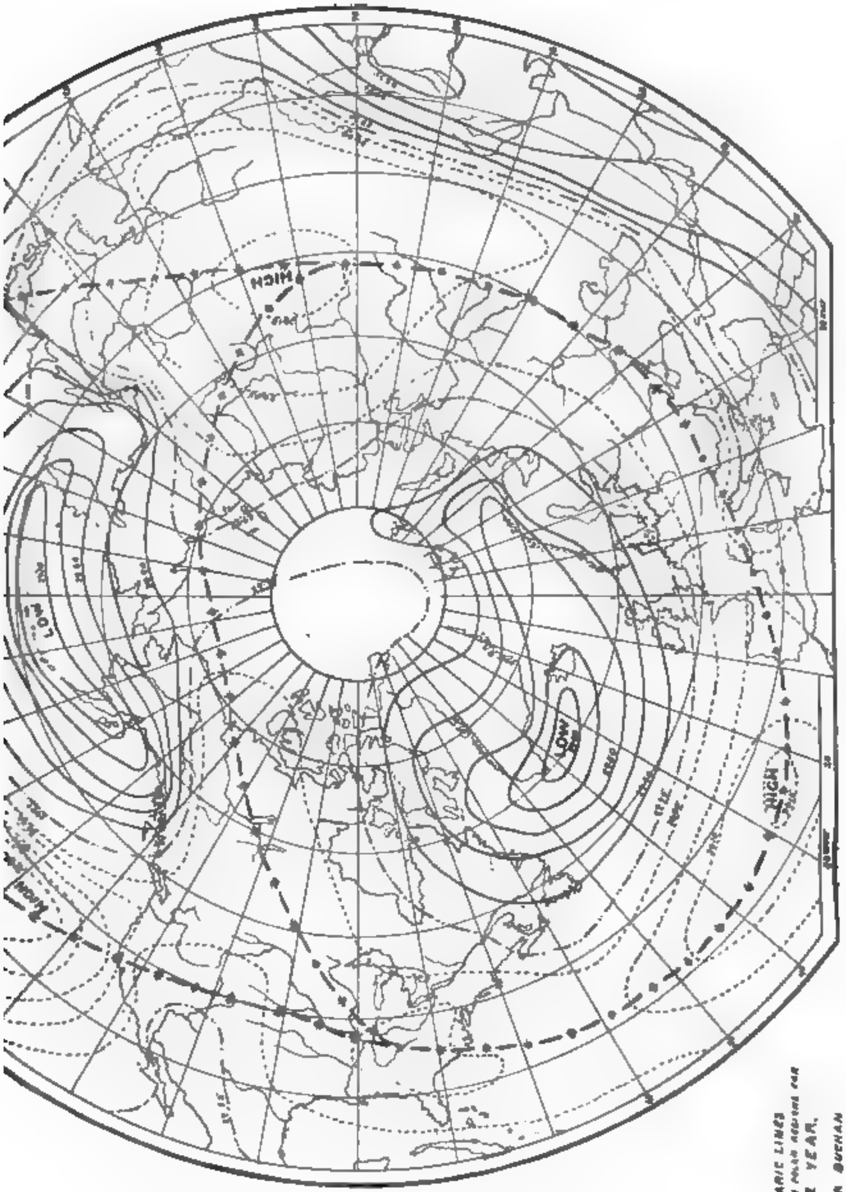
[1] Challenger Reports. Physics and Chemistry, Vol. II, Maps 51 and 52 These include the main data gathered by polar Stations.

[2] Berghaus Physical Atlas.

the general features of atmospheric pressure and circulation. An inspection of Buchan's isobaric maps shows that there are, north of 45° north latitude, two nearly permanent areas of *low* barometer and one of *high* barometer. (See accompanying sketch maps 1 and 2, based mainly on Buchan's.) The area of high barometer is located in Asia on the meridian of 100° east longitude. It may perhaps be regarded as one of the normal high areas that theoretically belong to the parallel of 30° north latitude, but which has been displaced 20° to the northward by the topographic conditions of the great Eurasian continent. Its two chief companions under this view lie, the one in the east Atlantic centering near the Azores, about 30° north latitude and 25° west longitude, the other in the east Pacific, off the coast of California, in about 35° north latitude and 140° west longitude. But the Asiatic area of high pressure seems to combine in itself also the function of a polar center, for no other center, high or low, lies between it and the pole. Moreover, it is above mid-latitude, and is nearer the parallels of the two permanent areas of low pressure of the arctic region than to those of its 30° correlatives, for it lies itself in 50° north latitude, while the arctic "lows" lie in 55° and 60° north latitude respectively.

Furthermore, as shown on Buchan's map 52, these high-latitude centers are arranged about the pole at nearly equal distances from each other, the Asiatic "high" being in about 100° east longitude, the north Atlantic "low" in about 35° west longitude, and the north Pacific "low" in about 170° west longitude, *i. e.*, their successive distances from each other are 135°, 145°, and 140°. While these centers shift somewhat during the seasons, they are essentially fixed, the above statements being based on the isobaric averages for the year. These centers are therefore to be distinguished from the familiar moving cyclonic centers and are to be regarded as enduring factors which express the essentially permanent circulatory features of the circumpolar atmosphere. The Asiatic "high" is a permanent anti-cylonic area characterized by descending outward-flowing currents, attended by low precipitation and clear air. The north Atlantic





ISOBARIC LINES
IN THE NORTH POLAR REGIONS FOR
THE YEAR,
AFTER BUCHAN

and north Pacific "lows" are permanent cyclonic areas with inflowing ascending currents attended by high precipitation and prevalent fogs.

Of the two "lows" that of the north Atlantic is the broader and more northerly, and appears to be the more influential factor now, as presumably it was in Pleistocene times. The north Atlantic "low," according to both Buchan and Hann, centers near the apex of Greenland; the north Pacific "low" centers on the Aleutian islands.

It is not difficult now to understand the peculiar behavior of the ice-drift of the polar seas. The Asiatic "high" with its outflowing currents pushes the ice off the Asiatic coast, while the currents inflowing toward the two "lows" impel it toward a point between the two. The Asiatic "high," however, develops more to the northeast of its center than to the northwest, and the North American area of moderately high barometer extends a tongue to the northwest between the two "lows," so that the two high areas approach each other north of the north Pacific "low" and reduce its influence upon the high latitude currents. These are therefore directed disproportionately toward the north Atlantic "low," and give to it a dominating influence. Buchan's maps of wind-directions for the winter months (when local influences are reduced to the minimum) show that the prevailing wind currents flow concentrically about the north Atlantic center from the Lena on the east to the MacKenzie on the west, a stretch of 220° longitude.

Correlation of circumpolar currents.—But in considering the circumpolar circulation as a whole, it is necessary to combine all the movements about all these centers to find the true dynamic center or the constructive pole of the winds. While such a combination cannot be accurately made from present data, it is obvious that it must place this constructive pole somewhere to the northward and westward of the north Atlantic "low" and nearer to it than to either of the other centers. The point toward which the ice-drift converges satisfies these conditions, and may be taken as nature's own practical correlation. Possibly

ıe magnetic pole may prove to be another expression of the ıme correlation, made indirectly through the agency of electric ıd magnetic dynamics springing from atmospheric circulation.

One-sided location of "lows."—As already noted, the two areas : permanent low barometric pressure are located on the Ameri- ın side of the globe and have their centers, according to Hann ıd Buchan, less than 140° Long. ($\frac{7}{18}$ of the total 360°) apart. hey are notably elongated in a general east-westerly direction, ıe north Atlantic area being especially extended easterly and ›rtheasterly, and somewhat curved and reniform. If the iso- ıric line of 29.95 inches, which represents the average pressure ›r the globe, be taken as defining the low areas, their borders ·e only about 40° Long. apart on the American side, while ıey are 115° Long. apart on the Asiatic side in about the same titude. In other words, the distance between the borders of ıe low areas on the American side is about one third of the stance on the Asiatic side. The distance between the borders : the "lows" is only about one half their own longitudinal ameters. The tract between the borders of the "lows" on the merican side being thus relatively narrow, it might naturally be ıticipated that the currents within it would be much influenced γ those of the adjacent depressions, and this seems to be in a rge measure realized, for the winds on the northern American ains east of the Rocky Mountains flow in the main concentric › the north Atlantic depression. On Buchan's map 52, which ıs a polar projection, the isobaric line of 30 inches describes :arly a circle about a point not far from the center of Green- nd's ice-field. (See sketch map 2.) In a rude way the pre ıiling winds within this circle and for some short distance ithout it whirl about the Greenland center with inward tend- ıcy. The influence of the north Pacific depression does not ›pear to be appreciably felt east of the mountains.

Relation of moving cyclones.—It is interesting to note in this ›nnection that many of the moving cyclones that traverse the id-latitudes of our continent seem to take their origin in the act between these two permanent cyclonic areas, or in the

region immediately to the south of it, and that possibly they
but secondary eddies generated by the action of the great fi
ones. As before noted, the migrant eddies swing concentrica
about the north Atlantic depression.

Location of present glaciation.—Coming closer home to
glacial problem, it is important to note that the two great a
of present arctic glaciation are intimately related to these
permanent cyclonic areas. The Alaskan and Greenland
fields not only lie within these areas of barometric depressi
but are peculiarly related to them. It is, at first thoug
not a little singular that, while the Alaskan ice-fields lie on
northeast border of the Pacific "low," the ice-fields of Greenl
lie in the *northwest* quarter of the north Atlantic "low;" that
the chief glaciations lie *between* the centers of the two perman
cyclonic areas. The apparent anomaly of maximum ice ac
mulation in the northwest quarter of the Greenland "low" pr
ably finds its explanation in the following considerations:

1. The maximum precipitation (which is normally found
the southeast quarter of a "low") and the maximum ice accun
lation should not theoretically be coincident; for the ice ac
mulation is not a true measure of the precipitation, but merel
measure of that *part* of precipitation which is frozen when
falls and survives melting and evaporation. Now in the no
and west quarters a larger percentage of the precipitation
snow than in the south and east quarters, where the sum total
precipitation is greater. Moreover, the melting in the no
and west quarters is obviously less than in the opposite quarte
The annual isotherms for the southeast quarter range from
up to 50° F., while those of the northwest quarter range fr
35° down to 0° F. The ice-fields of Greenland and the la
west of it lie in the tract whose annual average is below 32°
Iceland, whose precipitation is greater, but whose glaciation
less, lies between isothermals 35° to 40° F.

2. The configuration of the water area which wraps ab
Greenland gives special snow-precipitating efficiency to t
winds that swing about the depression on its north side a

s Greenland from the east and northeast. *The nature of irculation is such that Greenland is really on the leeward side of orth Atlantic.* This is shown by the following tables of preng winds. The first is from the prolonged observations rded at Godthaab and Upernivik, by Dr. Rink; the second, those taken under the direction of General Greeley at Fort ger in the years 1882 and 1883:

ENTAGES OF TIME DURING WHICH GREENLAND WINDS BLOW FROM THE DIRECTIONS NAMED

ction	At Upernivik Lat. 72° 47′. Long. 55° 35′				At Godthaab Lat. 64° 11′. Long. 51° 43′			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
.....	25.5	33.9	31.9	28.8	33.1	37.4	30.3	25.5
.....	34.3	23.1	16.2	36.5	38.4	24.8	8.6	33.6
.....	15.5	20.3	28.0	18.1	16.1	21.7	32.9	22.9
.....	1.8	2.5	6.4	4.4	4.9	5.7	15.1	6.2
.....	22.9	20.2	17.5	12.2	7.5	10.4	13.1	11.8
	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

FREQUENCY AND VELOCITY OF WINDS AT FORT CONGER, LAT. 80° 44′ N., LONG. 64° 45′ W.

Direction	1881–2		1882–3	
	Times	Miles	Times	Miles
....	393½	1522	420	2401
....	761	3061	1022	4613
....	1151½	4843	1369	4061
....	678½	3605½	862	3650
....	683½	3864½	775	4214
....	678	2011	900	3059
....	371	949	343	997
....	296	731	387	1142
....	3408	1282	2682	50

he winds of the summer months are much influenced by features, especially by the sea, the naked earth and the ice s, respectively, while in the cold months a nearly uniform le of snow or ice covers the whole surface in common, and ves essentially all sources of variation except those of

relief. Including the data of the summer months, the preponderant direction is shown by the above tables to be easterly. Omitting them, it becomes northeasterly. But in either case the dominant winds come from the north Atlantic, and justify the statement that Greenland is on the leeward side of the high north Atlantic and the adjacent part of the Arctic Ocean.

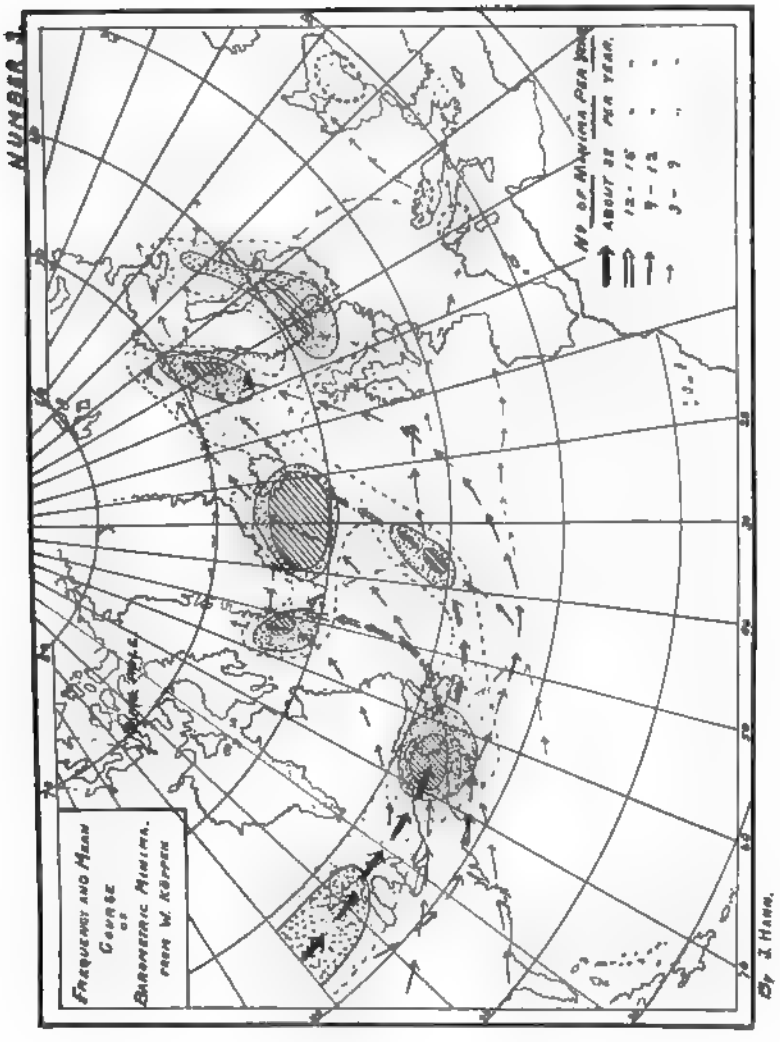
In the eastern part of the Arctic Archipelago as far south as Hudson Straits the winds are very variable, a fact quite consistent with their physiographic surroundings, and with their location well toward the interior of the north Atlantic depression.[1]

The paths of the moving cyclones.— Besides the general fact that the prevailing atmospheric currents from the Mackenzie to the Lena form a great eddy, with maximum conditions of glaciation on the north and west of its chief center near the apex of Greenland, it is to be noted that the paths of the moving "lows" are greatly influenced by the permanent depression at the center of the eddy. This is graphically shown for the north Atlantic portion of the region by Hann's map No. 36[2] herewith reproduced (sketch map 3), in which it is shown that nearly all the moving "lows" curve to the northward in courses more or less rudely spiral or concentric to the permanent "low." The larger number of paths run spirally in toward the permanent center, which suggests the conception that the great fixed cyclone is in some sense an aggregate of numerous small in-running migrant cyclones. If data were sufficient to permit the following of the complete courses of all the migrant cyclones from their origin to their extinction, a dominant system of great interest would probably be shown. As already remarked, a considerable number of these migrant cyclones originate in the American northwest.[3] These show a notable habit of sweeping southeasterly

[1] I am greatly indebted to the Hon. Willis L. Moore, Chief of the United States Weather Bureau, and to Professor R. F. Stupart, of the Canadian Meteorological Service for transcripts of data relative to various high latitude stations not otherwise at my command.

[2] Berghaus' Physical Atlas.

[3] "The North American continent is the region where cyclones form in large numbers, and Europe and Asia the region where they dissipate." F. H. BIGELOW: Am. Jour. Sci., Vol. VIII, December 1, 1889, p. 443.


NUMBER 1
No. of Minima per year
12 - 16
9 - 12
3 - 9
Frequency and Mean Course of Barometric Minima. From W. Köppen
By J. Hann.

into the Mississippi Valley, where they curve
the courses shown on Hann's chart. These c
into two classes, the one running spirally inwar
of the great fixed eddy, the other spirally outw
tendencies. A suggestion relative to the p
this last feature will be given in another conn

A more general view.—While all generali
tained must be held very tentatively, because
of present data, a general conception of the
northern part of the northern hemisphere,
bring together and give coherence and unity t
features which have been discussed, may be p

The whole temperate and polar region is
of high pressure (annual average above 29.9
in which the dominant currents are downwar
areas of low pressure (annual average below
mm) in which the dominant currents are in
The mutual disposal of these gives a basis for
the atmospheric circulation.

The high pressure loop.—In tracing the fo
for convenience, on the 30° latitude tract at
near the Azores, where it lies between 30° and
Tracing it thence easterly, it inclines notabl
at the meridian of 100° east, has made a no
latitude. Thence onward it continues to g
first more rapidly and then less rapidly to a
of 180°, when its course is nearly normal to
its latitude may be roughly taken as 75°.
course is south of east to the Mackenzie basi
southerly over the Canadian plains east of the
until it again joins the high tract that norr
latitude. It thus makes a great loop swingin
and passing near it at its climax in latitude,
great north Atlantic eddy (see sketch map
accentuated by nodes of an anticyclonic nat
these is the great "high" of Asia. This

southeast, and is constructively connected in that direction with the 30° belt, which develops a strong anticyclonic node near the California coast, beyond which it connects with the main tract which crosses the United States and the Atlantic near its normal position. Between this connection across the Pacific and the main loop before traced lies the Aleutian depression.

The high tracts of the northern hemisphere therefore form (1) a great loop embracing the great north Atlantic depression and, (2) incidentally, as it were, a minor loop embracing the north Pacific depression. The great loop is not conceived as a current, much less a whirl, but as a tract along which the upper atmosphere habitually descends with outflowing tendencies. The enclosed area of low pressure is a tract over which the lower atmosphere habitually ascends with inflowing tendencies.

Now the main loop and the main enclosed eddy lie on one side of the northern hemisphere and embrace the chief area of Pleistocene glaciation. This main loop and its enclosed eddy embrace about three fourths of the hemisphere north of 30° N. Lat. In the area left vacant, so to speak, the secondary Aleutian eddy is developed and covers the main area of the Cordilleran Pleistocene glaciation.

There can be no question that this peculiar configuration is due to physiographic influences, particularly the oblique attitude and peculiar oceanic circulation of the Atlantic, and the similar obliquity of the main body of the eastern continent. To realize the full force of this obliquity one should trace on a globe the great axis of the eastern continent from Cape Verde on the protruding portion of Africa to Cape East at the extremity of Asia, an immense spiral, and then, starting from the coast of South America near the lesser Antilles, trace the axis of the North Atlantic to the heart of the Polar sea in a similar great spiral, essentially parallel to the former. With these primary influences many secondary ones are joined, some acting concordantly to intensify the obliquity of the circulation, and others acting discordantly and tending to destroy its symmetry, and modify its configuration.

This discussion of the present circulation, too protracted for this place, yet too brief for its purpose, has seemed necessary to make clear the conception entertained respecting the agencies of localization. It has previously been urged in this paper that a reduction of the carbonic acid in the atmosphere and the consequent reduction of its heat-absorbing capacity must intensify the influence of all surface features. In the discussion of existing glaciation I have endeavored to connect the present great ice-fields genetically with the two great areas of low pressure, and to associate them with an oblique disposal of the great circulatory features. The chief centers of present glaciation lie on the borders of the American continent. The chief Pleistocene glaciations, were concentrically arranged about these centers. As has been pointed out by other students of Pleistocene glaciation, the great northeasterly ice-sheet had its western, southern and southeastern limits almost coterminous with the predominant paths of northern migrant cyclones. To complete the hypothesis of localization it is therefore only necessary to assume an intensification of the present oblique system of circulation, with a further shifting of the centers of depression in the direction of the present displacement, accompanied by a sufficient depression of temperature. And these are the effects assigned to a reduction of the atmosphere's thermal capacity due to loss of carbonic acid.

Suggestion relative to migrant cyclones.—One further feature deserves notice. If the constructive pole of the winds lies somewhere between the earth's pole and the American continent, the frictional action of the earth will affect the two sides of the eddy in opposite senses. On the western side (from the American point of view) the friction will tend to drag the bottom air toward the cyclonic center and crowd the isobars upon each other. As the lines of the wind circulation and the earth rotation cross each other obliquely, a predisposition to form gyratory or cyclonic eddies may be inferred, and this may be one of the sources of migrant cyclones which may be regarded as small eddies in the grander cyclonic movements.

On the eastern side of the pole of the winds, the earth movement tends to drag the bottom air away from the center and this is perhaps one of the reasons why the moving cyclones on that side show a tendency to dispersal, both in course and in force, as previously noted.

Possible relation to terrestrial magnetism.— It is scarcely appropriate to this paper, if it were in my power, to discuss the relations of this oblique system of atmospheric circulation to the oblique system of terrestrial magnetism. Crudely stated, the notion entertained is that an atmosphere charged with electricity, circulating obliquely about a rotating earth which is inset with magnetic and magnetizable matter, might give rise to a magnetic system which should express the dynamic resultant of the atmospheric circulation. A comparison of the magnetic and atmospheric charts shows so many points of resemblance, some of which are striking *peculiarities*, as perhaps to justify this tentative notion until the mystery of the earth's magnetism be solved. Connected with terrestrial magnetism are auroral manifestations whose distribution is notably similar to that of the chief Pleistocene glaciation, as was remarked many years ago when first the progress of exploration outlined the extent of the glacial deposits. It can hardly be presumed that either terrestrial magnetism or auroral displays have in themselves any causal connection with glaciation, but if they are dependencies of atmospheric circulation they become eminently serviceable to glacial students by affording a tangible concrete expression of the dynamic correlation of the atmospheric circulation, free from the intricate complexities of the latter; in short, a natural resultant at easy command. The verity of the notion must, of course, depend wholly on the outcome of magnetic investigations on their own lines, which happily are now being vigorously prosecuted.

SUGGESTIONS RELATIVE TO MINOR GLACIAL OSCILLATIONS

It has already been noted that besides the oscillations of epochal order there were subsidiary ones which left their record in a series of concentric moraines which corrugate the individual

sheets of glacial débris. The latest drift she
That designated Wisconsin is accentuated b
peripheral ridges. In a recent admirable pa
is shown that similar lines of halt, and perhap
mark the corresponding European glacial sh
the plains of north Germany; indeed, even in
details, a striking correspondence is traceat
series, whose general identity in age and ki
noted by Salisbury.[2] These minor oscillator
therefore, sufficiently general and sufficiently
an explanation, and this explanation is not n
with the fundamental cause of glaciation.
cussion carries in itself a suggestion which i
passing. If the localization of the great ice
ent on the general circulation of the atmos
shifting of the circulation of moderate magni
petent to cause a shifting of the ice-sheet
nature. There are historical facts that give
notion that such shiftings have taken place
human records. The oscillations of existing
similar direction. There is clearly a secula
trial magnetism, but the nature of its cycle i
Current opinion gives it a periodicity whic
satisfy the demands of the concentric morair

GLACIATION NEAR THE CLOSE OF THE P

While the occurrence of extensive glacia
tralia and South Africa near the close of the
be regarded as fully established, a specifi
origin along the lines of an atmospheric hyp
midable difficulties, because the exact date o

[1] Die Stillstandslagen des letzten Inlandeises und die I
elung des pommerschen Küstengebietes. Separatabdruc
königl. preuss. geologischen Landesanstalt für 1898. Berli

[2] Terminal Moraines in North Germany. Am. Jour.
Series 3.

immediate antecedents and the nature of contemporaneous conditions in other parts of the world are not yet satisfactorily determined. No embarrassment attends a merely general application of the atmospheric hypothesis set forth in this paper, and perhaps it would be wise in the present state of knowledge to be content with such general application. But the main purpose of the paper — to develop a *working* hypothesis, helpful in the promotion of investigation — would be measurably defeated thereby, for a general theory merely supposed to be applicable in some indefinite way, not even specifically thought out, much less shaped to promote definite inquiry, falls short of working qualities. Were the Paleozoic glaciation a high-latitude phenomenon which could be referred to the same category as the Pleistocene glaciation, we might well leave specific discussion until further data were afforded, for few additional doubts as to the verity of the hypothesis and probably few new lines of inquiry would be raised. But the Paleozoic glaciation presents characters so extraordinary as to render it the supreme problem of glaciation. In it every hypothesis finds its severest test. No hypothesis that does not, in some remote way at least, approach an elucidation of this supreme case can have serious claims to acceptance as a working theory. It is, therefore, imperative to frankly and fully recognize this crucial problem and deal with its difficulties as well as existing data permit. A really satisfactory discussion is quite impossible in the present nature of the case. The attendant atmospheric and geographic conditions must be postulated, consciously or unconsciously, but the data for such postulates are imperfect and their interpretation is at best not more than probable. It is hoped, however, that fairly good reasons can be assigned for everything assumed in this paper.

The essential facts that make the Paleozoic glaciation a peculiarly strenuous problem are these :

1. It occurred in an early stage of the earth's history. No appeal can, therefore, be made to an advanced state of secular cooling leading on the "final winter" nor to any senile condition

inherent in an aged earth. If the traditi primitive atmosphere constituted a vast store ually drawn upon throughout the ages in t coals and carbonates, and was their chief sou at the close of the Paleozoic era must still l and dense to a degree far surpassing the ; state, for vast deposits of coal and carbona made through its agency. One of the most as most competent estimates of the consump since the Paleozoic era places it at 5000 tim tent. To be conservative, let this be halve and still the content of carbonic acid is 125(present. This atmosphere was so differen Pleistocene and present period as to rend inapplicable, all arguments founded upon th latter. The question of the constitution of t phere is, therefore, fundamental, because it af of all arguments based on present or recent with the above excessively reduced estima atmospheric environment in which any know to the case can be reasonably postulated as general glaciation? In such an atmospher phere greatly richer than the present in heat- retaining qualities, are there any sufficient g supposing that any of the putative causes of tion, whether topographic, geographic, latitud could produce such a glaciation as is record of the far Orient. It is not a part of the pu of this paper to antagonize other hypotheses their development into working coöperatic with that herewith advanced; but a whole hypotheses will be best attained by elimina ble grounds and by bringing all hypothes conditions of competency. It is, therefore, my purpose to urge the question whether all required, for their own conservation, to acce

fundamental postulates of the atmospheric hypothesis as are needful to give an atmosphere compatible with glaciation under such other conditions as prevailed in India, Australia and South Africa in the later Paleozoic.

2. The localization was most extraordinary. The chief areas lay under the tropics — the Indian, under the Tropic of Cancer and the Australian and South African, under the Tropic of Capricorn. The Indian area stretched southward to 17° 20′ N. Lat. and northward to the vicinity of 35°. The Australian area stretched north to 20° 30′ S. Lat. and southward (in Tasmania) to 42°. The extent of the South African area is less well known, but centers about 30° S. Lat. It appears then that on both sides of the equator glaciation reached two or three degrees within the tropics, while in the opposite direction general glaciation has not been traced beyond 42° To the south this signifies little because of the prevalence of the sea. To the north the apparent limitation is very singular and doubtless very significant. It cannot, however, be positively asserted that glaciation did not prevail in the higher latitudes, but no decisive evidence of it has yet been discovered. At the same time it must be recognized that many evidences of remarkable transportation and of unusual bowlder accumulation, and indeed of occasional striation have been reported, and that these have been attributed to glacial agencies by geologists of high standing. It cannot be affirmed at present that these phenomena were precisely contemporaneous with the glacial deposits of the oriental tropics, but they were nearly so.

In the southern portion of Brazil there are deposits strikingly similar to the glacial beds of Africa and Australia, but no striation or distinctive marks of glaciation have yet been authoritatively reported.

The southernmost extent of the lowland Pleistocene glaciation was about 37° N. Lat. The Paleozoic glaciation, therefore, reached 20° farther.

The altitude of the glaciation.—Respecting the altitude at which the Paleozoic glaciation took place, it is to be remarked

that in some cases there is so intimate a
marine deposits as to indicate that the ice re
and discharged icebergs. The associated
not seem susceptible of explanation by me
through the action of the ice, because of t
their position in the embracing sediments.
that certain bowlder-bearing mudstones "co
estellæ and bivalve shells, with the valves st
that they had lived, died, and been tranquil
they are now found, and proving, as conclus
in which they are preserved, that they coulc
exposed to any currents of sufficient force an
port the blocks now found lying side by side
included fragments of rock are of all sizes fr
several feet in diameter."

These and other evidences leave little ro
part of the glaciation at least affected low
other hand, most of the glacial beds are so r
glaciated floor as to show that they were f
This is confirmed by the nature of the striæ,
transported blocks to their source, and the
glacial beds with fresh-water deposits. At p
glacial beds are 3000 to 3500 feet above sea
but in general they are much lower. How m
is due to subsequent changes I do not know.
much evidence that the glaciation was not of
at least not simply of the alpine type. It
areas of moderate slope.

In kind of glaciation and in topographic r
zoic phenomena seem to have been of the
Pleistocene.

Approximate age.—Professor David and ot
of recent date do not attempt to locate the ho
tion nearer than Permo-Carboniferous. It is
Salt Range in northwestern India a Productus

[1] R. D. OLDHAM: Rec. Geol. Surv. India, XIX, 1886.

bowlder beds. From this and other paleontological evidence it would seem that the lowest of the glacial deposits at least antedated the disappearance of the Permian faunas from the seas.[1] It is unfortunate that the peculiar nature of the formation, and the not less peculiar nature of the associated flora, make it impossible at present to fix its exact horizon in terms of the European and American standards, so that the contemporaneous conditions in these regions could be determined. However, for the application of the atmospheric hypothesis the foremost question is the relationship of glaciation to the great agencies that affected the constitution of the atmosphere. These agencies were (1) the formation of coal, and (2) chemical reaction between the air and the earth's surface.

1. Relative to the first, it is certain that the glaciation closely followed the great coal-depositing period, and indeed fell in with the latest stages. In Australia there are considerable deposits of coal (the Gretna Coal Measures, embracing twenty to forty feet of coal) deposited "between the erratic-bearing horizon of the lower marine series and the similar horizon of the upper marine series" (David).[2] If, therefore, we look to the deposition of coal as the agency of atmospheric exhaustion, the relationship is nearly ideal.

2. If we look to elevation, and consequent large earth-contact, the relationship does not appear to be what theory would demand. It can scarcely be questioned that at the close of the Paleozoic period there was a very unusual surface movement, affecting great areas of the earth's surface and increasing largely the exposure of the land. The period appears to have been altogether comparable to that at the close of the Tertiary period. If we were seeking the cause of the glaciation assigned to the Triassic, or the occasion of the salt and gypsum deposits

[1] There is some evidence of another glacial horizon at or about the base of the Triassic (well indicated in White's excellent synopsis, Am. Geol., May 1889, table, p. 315). The present discussion will, however, be confined to the lower horizon, that of the Talchirs and their equivalents.

[2] Quarterly Jour. Geol. Soc., Vol. LII, May 1896, p. 300.

so widely prevalent in the Permian and Trias
elevatory movement would stand in the proj
if present evidence is to be trusted, it doe
proper antecedent relations to the Permo-Ca
tion, at least not as the primary agency. S
an absence of evidence of large exposure of
atmospheric degradation for a notable per
Permo-Carboniferous glaciation, there are
believing that the great era-closing movemei
had made notable advance even at this time.

The Gondwána elevation.—The glacial be
tion form the basal members of the remarkab
the chief members of which are land and fi
These in themselves imply a recently rejuve
for an ancient topography has a perfected d
adjusted gradients. It is the dominant belief
most studied the region circumjacent to the
the formation of the Gondwána series and th
distribution of the remarkable Glossopteris
sions and connections of land of a somewha
this belief were accepted to the full extent ur
advocates, it would in itself involve a very lar
not disposed, however, to force the doctrir
continent beyond the most modest limits, hov
contribute to a favorable reception of the hy
cussion. It appears to me that the distribut
teris flora may be in some notable part a c
a topographic effect; that is to say, the p
conditions, of which glaciation was the supre
tinguished that quarter of the globe from t
themselves have controlled the distribution of
question. It may therefore only be necessa
an extension of the land as was required to p
of the flora and its companion fauna.

However this may be, it is very generall
notable land extension prevailed as early as

stribution of the Glossopteris flora. It will be quite conserva-
'e to assume that this involved a land connection between
dia and Australia, and probably New Zealand, the connection
esumably lying along the submerged platform which even to
is day stretches southeasterly from Asia to the islands in
iestion with slight interruptions. It is not improbable that
tween India and South Africa at least a partial bridge was
rmed by the elevation of the submerged plateau on which
adagascar and the Seychelles rest, together with the tract
w accentuated by the Maldive islands.

A connection with South America (where the Glossopteris
ra also appeared — southern Brazil and Argentina) involving
e least radical departure from modern configuration, may have
en made via New Zealand and the Antarctic continent. This,
elieve, also best satisfies the general tenor of paleontological
idence.

If the geographic changes were confined to such connections
d extensions of land as these, and to such moderate eleva-
ns as the nature of the glacial beds and the associated deposits
em to imply, and to such changes in the northern hemisphere
can fairly be assigned to the Permo-Carboniferous period,
ere does not seem to be adequate ground for attributing a very
ceptional depletion of the atmosphere to land-contact alone,
chiefly, though it may have made some notable contribution
that direction.

Effects of atmospheric depletion by coal deposition.—We there-
e turn to coal-formation as the effective alternative. There
no reliable estimates of the total carbon in the coal and
rbonaceous deposits of the Carboniferous period, but such
proximations as have been made seem to show that it equals
veral times the present atmospheric content, and that its
traction superadded to the increasing formation of carbonates
sulting from the rising land would have been competent to
luce to the point of glaciation an atmosphere three or four times
rich in carbon dioxide as the present; in other words, such
atmosphere as the sub-Carboniferous climate seems to imply.

A question of no small interest is the special kind of eff
which an atmosphere reduced by coal formation would indu
as distinguished from that induced by depletion through ear
contact. In the latter, as already set forth, bicarbonates w
the chief product, and carbon dioxide, temporarily locked
played a very important part. Through the peculiar agency
the ocean this "loose" carbon dioxide hastened the devel
ment of glaciation, prepared the conditions for strong react
and accelerated the reaction when inaugurated. In the form
tion of coal and like products no such effective temporary fac
is produced. The carbon is, to be sure, temporarily held in
vegetation, but so much as decays goes directly back into
atmosphere, in the main, and the rest becomes permanently fix
Neither part goes into an intermediate state of reserve, subj
to being called forth by change of conditions as in the case
the second equivalent of the bicarbonates of the ocean. T
action is somewhat analagous to the original carbonation of t
silicates of the crystalline rocks in which the first equivalent
carbon dioxide when once united remains fixed (barring accide
to which coal is also liable), but in this case there is also
second equivalent of carbon dioxide temporarily locked up
long as a state of solution is maintained. Succinctly stat
without the unessential qualifications: (1) Depletion by c
formation is accompanied by no intensifying and reactive fact
(2) Depletion by conversion of silicates into carbonates
accompanied by an intensifying and reactive factor; (3) Dep
tion by the solution of limestone is wholly temporary in nat
and specially capable of promoting intensification and reacti

If, therefore, the impoverishment of the atmosphere as t
prerequisite of glaciation in Permo-Carboniferous times was d
in the main, to the extraction of carbon in the form of coal a
like deposits, there was absent, to that extent, the factor to whi
the hastening of glaciation and of reaction is assigned. Befo
glaciation could be affected in the measurable absence of t
accelerating agent, it was necessary for the permanent depleti
to go to greater lengths. Moreover the depletion when on

affected was essentially a non-reactive one. Of course the reactive factor was never really absent, for the formation and solution of carbonates was always in progress. In this case it is merely supposed to be the minor rather than the major factor. It is inferred, therefore, that a higher stage of permanent depletion of the atmosphere was reached before glaciation ensued through coal formation than would have been the case had the glaciation been produced by the formation of carbonates. To this, in a measure at least, is attributed the conditions which made it possible for the glaciation to affect lower latitudes in Permo-Carboniferous times than they did in Pleistocene times. As before noted, the Permo-Carboniferous glaciation extended 20° nearer to the equator than the Pleistocene.

The localization of the Permo-Carboniferous glaciation.—It remains to consider the remarkable localization of this ancient glaciation. The general principles involved are assumed to have been the same as those already applied to the Pleistocene problem, but the geographic factors were quite different, and it is here that the lack of complete data is most keenly felt. In Pleistocene times, as also at present, certain great geographical features are thought to have given a pronouncedly oblique circulation to the air currents of the northern hemisphere. In the southern hemisphere at present a much greater approach to symmetrical circulation prevails because great oblique features are absent. It is postulated that the configuration of Permo-Carboniferous lands and oceans was such as to seriously disturb the symmetry of the atmospheric and oceanic circulation of that hemisphere, and to give it peculiar form and special intensity.

The geographic features of the Permo-Carboniferous period.—The assigned changes introduced by the development of Gondwána land have been mentioned. These are thought to have prolonged the Asiatic continent southeasterly to Australia, and probably to New Zealand, and perhaps to the Antarctic land. This prolongation, taken with its backward projection across Asia and Europe, constituted an oblique feature of great extension. It also interposed a barrier which very notably modified

the water connections of the Pacific and Indian oceans. Tl warm equatorial currents which now flow through the numero straits of the East Indies and add warmth to the Indian Oce were turned back, and their heat retained in the Pacific. the same time the cold currents of the southern Indian and tl adjacent Antarctic oceans were shut out measurably or whol from the Pacific, and turned northward into the equatori portion of the Indian Ocean. There was thus a concentration heat in the one and of cold in the other. If the suggested co nection of New Zealand with the Antarctic continent was mad these cold southern waters would have been effectively shut o from the Pacific and forced to circulate through the Indian Ocea If the other conservative changes suggested to meet the deman of the Gondwána phenomena were realities, the Indian Ocea took the form of a great triangle with a very broad base in th antarctic regions, and a narrowed apex reaching across th equator to the vicinity of the Indian glaciation.

In the north Atlantic region there is evidence that the gre readjustment which closed the Paleozoic era had made notab advances at the probable time of the Oriental glaciation Tl New Red Sandstone of western Europe is not unlike the Gon wána series in general characters, and indicates a like rej venated land. Within it also are found arkose, conglomerat and breccias, often formed of large, far-transported block "Some of these blocks are three feet in diameter, and show di tinct striation. These Permian drift beds, according to Ramsa cannot be distinguished by any essential character from mode glacial drifts, and he has no doubt that they were ice-born and, consequently, that there was a glacial period during th accumulation of the Lower Permian deposits of the center England."[1] There is good ground to believe that previous t the formation of these deposits the land on the European bord of the Atlantic had risen relatively. There are similar evidence on the American side. The close relations between the lan faunas and floras on the two continents strongly imply a fre

[1] SIR ARCHIBALD GEIKIE: Text-Book of Geology, p. 753.

land connection. This is most pointedly indicated by the distribution of the amphibians of the Carboniferous and Permian periods. The Branchiosauria, Aistopoda, Microsauria, and Labyrinthodontia vera were all represented on both continents, and unless the doctrine of parallel evolution be pushed to a seeming extreme, the only satisfactory explanation is an ample land connection. The amphibians of today are fatally affected by salt water, and even their eggs lose their vitality after a short submergence in it. It cannot be positively affirmed that this was true of the Carboniferous amphibians, but the presumptions appear to lie in that line. At any rate the occurrence of all the leading branches on both continents renders it quite improbable that a broad ocean intervened. It is therefore assumed that the Atlantic Ocean was restricted at the north by such connection. To be definite, it is assumed that it essentially terminated south of the Greenland-Iceland-Faroe platform, or possibly south of the Telegraphic plateau.

There are few data that give specific indications as to the configuration of the north border of the Pacific at this time, but the considerations that have just been urged with reference to the distribution of the fauna and flora are apparently best satisfied by supposing an emergence of the very slightly submerged continental platform of the arctic region generally. This is in harmony with the history of the preceding Paleozoic periods during which the Eurasian and North American continents were essentially a unit and free migration from one to the other was an oft-repeated, if not predominant, phenomenon. If this be the true inference the Pacific Ocean was limited at the north to about 60° Lat.

In equatorial latitudes it is not improbable that the Atlantic and Pacific oceans were united between the main bodies of the North American and South American continents, so that a commingling of waters took place here not unlike that which now obtains between the Pacific and Indian oceans.

It is not improbable also, judging from the distribution of Permian marine beds, that inland seas extended along the

Mediterranean tract into eastern Europe and perhaps to the Caspian-Ural region of Asia; indeed, it is not altogether improbable that straits or narrow seas may have connected with the apex of the Indian ocean. At least in the later Permian times the marine faunas of India and of Europe were notably similar, and in the early Mesozoic they became so nearly identical as to make a connection along this line extremely probable.

Effect of the supposed geographic changes on atmospheric circulation.—While none of these postulated changes involve great terrestrial movements, or depart widely from the rather definite indications of the phenomena concerned, it will be seen upon a study of the resulting distribution of land and water that they probably profoundly affected the circulation of the atmosphere. The limitation of the Atlantic at the north by the European-American connection rendered it essentially an equatorial and warm temperate ocean. Its present high-latitude connection, involving the transportation of vast quantities of ice and cold water into it from polar regions and the reciprocal loss of heat borne into the high latitudes by the Gulf Stream, was eliminated. The atmospheric function of the Atlantic was, therefore, radically changed. That great oblique factor to which was assigned so large a function in the localization of Pleistocene glaciation, was largely absent from the Permo-Carboniferous circulation. To the similar restriction attributed to the north Pacific a minor limitation of a like kind may be assigned. Instead, therefore, of a polar sea exchanging its thermal properties with an equatorial sea, as at present, there would be substituted a prevailing polar land, relieved probably only by the deep basin of the Arctic sea, whose limited extent and land-locked situation would render it little more significant in general climatology than the present Mediterranean.

On the other hand, very notable oblique features appear in the equatorial and southern regions. The postulated changes of the Pacific Ocean, by shutting off its connections with the Indian Ocean, probably brought into effective influence its long northwesterly and southeasterly trend, now neutralized by its

westward connections. In other words, the somewhat balanced distribution of the present Pacific was replaced by an effective obliquity which could scarcely have failed to powerfully influence the general circulation of the Paleozoic atmosphere. The northwest-southeasterly extension of the great Eurasian-Australian land paralleled this and intensified its effects. In other words, the Pacific Ocean and the parallel Eurasian-Australian continent constituted, in Paleozoic times, a couplet of oblique features that were chiefly effective in the equatorial zone and the southern hemisphere. They replaced the similar pair now formed by the north Atlantic and the eastern continent. It is inferred, therefore, that an obliquity of circulation of a pronounced order prevailed in Permo-Carboniferous times, by virtue of which the southern hemisphere was brought under the influence of meteorological agencies analogous to those that in Pleistocene times affected the northern hemisphere.

Some differences, however, are to be noted. The equatorial zone was then profoundly affected by the oblique features which lay directly athwart it. In addition to this there was the peculiar configuration of the Indian Ocean already set forth, namely, a broad, open mouth extended to the Antarctic polar regions, with a convergence to a narrow equatorial apex 20° or more north of the equator. The general course of the circulation in this may be assumed to have been much as it is today; that is, a movement in the polar latitudes, at first northerly and easterly, then curving about to the northward and northwestward as it approached the equatorial zone, and at length returning to the southwest along the African coast, thus forming a free circulation between the high latitudes and the low latitudes, with high latitude influences greatly preponderant. This circulation in Paleozoic times may be reasonably assumed to have been much more intense than at the present time, first, because there were then, by hypothesis, greater intensities of temperature, and second, because a larger percentage of the Antarctic waters were forced to flow into the apex of the Indian Ocean by the configuration of the land. This last statement would hold true even

if New Zealand were not connected with the and South America, for the avenue of escap would be circumscribed by the minimum e Gondwána phenomena seem to require. If t American connection were made, it would fo cumpolar circulation, and all the polar ic America to New Zealand would doubtless b erly into the Indian Ocean. This would c intensity to the circulation of the polar cu Indian Ocean. The temperature of the latter radically affected by the immense quantiti water carried through it by this intensified ci atmospheric conditions postulated. A like upon the overlying atmosphere must necess The narrow apex of the ocean under the trop have afforded little relief from the dominanc

If this cold area be contrasted with the should naturally prevail in the Pacific Ocean, breadth under the equator, its limitations at somewhat narrow communication at the sout be shut off from the Antarctic flow past Ne give rise to antithetical conditions of temper sufficient to radically influence the general southern hemisphere. It is conceived that couplet might even introduce a systematic e pheres between the northern and the souther sisting essentially of a cold north-seeking cu the Indian Ocean into the northern hemisph a warm return current flowing from the north hemisphere across the tropical regions of t conception is not regarded as a vital part of t

The configuration of the Atlantic is suppo it to play a subordinate part, the northern po auxiliary of the Pacific and the southern po largely an auxiliary of the Indian Ocean. If Gondwána extension connected New Zealand

ands and South America, the ocean currents may be pictured as sweeping eastward from South America along the icy borders of the Antarctic continent into the great bay south of Australia, out of which they recurved and flowed northward across the equator to the Indian peninsula, which they freely bathed, and, returning along the supposed Gondwána connection, wrapped about South Africa and then flowed northward toward the equatorial regions, a portion then curving backwards and descending the coast of South America to complete the circuit. Such a circulation would throw perhaps two thirds of the antarctic influence into the Indian Ocean. On the other hand, seven eighths or more of the equatorial influence would probably be brought to bear upon the Atlantic and Pacific oceans. As a result these oceans, notwithstanding the impoverished condition of the atmosphere, received and retained a large percentage of the sun's heat.

Referring to the principles stated earlier in this discussion, it may be remembered that it was noted that a diathermous atmosphere permits a larger part of the sun's heat to reach the surface of the earth than a thermally opaque atmosphere, and that the portion which falls upon the ocean for the most part penetrates it until it is absorbed. A certain part, to be sure, is reflected, but in the zone of nearly vertical rays this is reduced to the minimum. As the result of the ocean's ability to absorb and retain heat, the diathermacy of the atmosphere is of less consequence in equatorial oceanic regions than in land tracts and hence the great equatorial oceans may have remained measurably warm throughout the glacial period.

It is conceived, therefore, that under these conditions, glaciation may have been produced in exceptionally low latitudes, and that its distribution was closely associated with the Indian Ocean. At the same time it is conceived that the lands immediately adjacent to the Atlantic and Pacific oceans, especially in low latitudes, were so far affected by the favorable thermal condition of those great bodies as to enjoy relatively mild temperatures, at least temperatures sufficiently genial to save them and the

adjacent lands from the exterminating effec
ally be associated with a glaciation in the trc

Relative to the more specific location of t
rous glaciation, it may be noted that a tende
in India, Australia, and South Africa, not f
glaciated areas, is observable even under the
It is presumed that much more pronounc
Permo-Carboniferous times, located on the b
belt formed by the intensified antarctic circul
determined the areas of specific glaciation.

Conditions in the northern hemisphere.—In t
very low temperature may be confidently postu
posed conditions, because of the extent of the l
of oceanic circulation between the high north
regions. A Siberian climate of an intensified
assumed to have prevailed over the high latitu
hemisphere. This may doubtless have gi
accumulations of snow in favored localitie
glaciers, but on account of the general lo
the dryness of the atmosphere, giving rise to
this may not have become a pronounced fact.
deposits originated in the interior of the l
liable to destruction by surface denudation b
The Permo-Triassic land period was long.
already noted, there are phenomena which
explanation in glaciation and ice transport
anticipated that, if this view be correct, fur
severe temperature in northern latitudes will
course of future studies. It may be remarke
nearly as much evidence of Permian glaciati
hemisphere in regions away from mountains as
cene glaciation in the southern hemisphere in

As remarked at the outset of this part of
satisfactory discussion of the Permo-Carbon
impossible in the present state of knowledge.
blind to the uncertain factors that inhere,

lations, in the geographic features, and in the meteorological
ferences drawn from them. The most that could be hoped
om an attempt to explain so extraordinary phenomena in so
iperfect a condition of the data is to suggest the general direc-
on in which, perchance, the truth may ultimately be found to
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T. C. CHAMBERLIN.

EDITORIAL

THE "Commissão Geographica e Geologi
São Paulo, Brazil, has just issued its first to
preliminary edition of the "folha de S. Paulc
minutes sheet on a scale of one to one hun
contours twenty-five meters apart covering
São Paulo and Santos, and including both
crosses one of the most characteristic and i
topography of all South America — the Serra
of coast shown in the vicinity of Santos i
istic one, while the high plateau of the int
shown between the crest of the serra ar
Paulo.

Among other things brought out by this
of a late depression of the coast. The bay
estuaries thereabout are the remnants of a
island-dotted bay that extended from Guar
coast to Cubatão at the foot of the Serra. T
that protrude from the marshes about Sa
summits of mountains whose bases were c
ocean water by this depression.

The map is printed in three colors: the h
the topography in brown, the remainder in
ance it is up to the highest standards of m
and reflects great credit upon everyone
preparation and publication. That such w
vided for by the State of S. Paulo, and that t
the patience to await the slow and tedious pro
tion, field work, office work, and all the othe
good map, is the most healthful and encou
have yet seen of the high intelligence and

t part of South America. It is pleasant to note that this portant work has been entrusted to our fellow countryman l colleague, Professor O. A. Derby, and that his chief topog-her, Mr. Horace E. Williams, received his training in this intry.

J. C. BRANNER.

A REFERENCE LIST OF SUMMARII TURE ON NORTH AMERICAN GEOLOGY, 1892 TO THE CLOSE (

In the Archean and Algonkian Correlati Van Hise (Bulletin 86, U. S. Geol. Survey, 1 can pre-Cambrian literature was fully summa of the earliest publications to 1892. Since pre-Cambrian literature have been published in the JOURNAL OF GEOLOGY by C. R. Van Hı been continued in the same periodical by summaries thus far published are supposed t pre-Cambrian geology for North America fro of 1898. To facilitate reference to the sumı articles there is given below a list of the a arranged alphabetically according to author with the volume and page of the JOURNAL in appears. At the end there will be found a regions of pre-Cambrian exposure, and und names of the men whose articles on the pr area have been summarized.

The summaries here listed and those to 1899 and 1900 will serve as a basis for a bu under the joint authorship of C. R. Van Hi supplementary to Bulletin 86, U. S. Geol. Sur that there are a number of omissions and erro listed, and it is hoped by sending out this number of them may be noted and brought to

[1] The summaries have appeared in the JOURNAL OF GE
Vol. I, 1893, pp. 304–314, 532–541.
Vol. II, 1894, pp. 109–118, 444–454.
Vol. III, 1895, pp. 227–236, 709–721.
Vol. IV, 1896, pp. 362–372, 744–756.
Vol. VI, 1898, pp 527–541, 739–753, 840–854.
Vol. VII, 1899, pp. 190–205, 406–425, 702–708.

authors, who would be glad to know also of any errors or omissison in Bulletin 86 itself. Any correspondence with reference to them should be addressed to C. K. Leith, Madison, Wis.

In order that the purpose and scope of the summaries may be clear to every one, there is repeated below the prefatory note published by C. R. Van Hise with the first lot of summaries appearing in the JOURNAL.

The summary proper and the comments are kept wholly separate, in this way preventing the confusion which frequently comes from a mingling of the two. In the summaries the original language of the author is used as far as practicable, although a single sentence may be taken from several sentences of the original. Where it is disadvantageous to use the original language, other words are used. This often is necessary because the language which is adapted to complete exposition is often not the best adapted to résumé. No quotation marks are used; for the ideas contained, whether in the original language or not, are wholly the ideas of the author, and the whole is in fact quoted. It might be thought that better results would be reached by indicating through quotations what words are taken from the original, but this method would necessitate an unpleasant and constant alternation from quoted to non-quoted phrases. As a result of experience with the two methods, the editor feels certain that he is able more accurately and fully, in a brief space, to represent the ideas of the original author by the method proposed, than by following the usual method.

The summaries are confined to articles or parts of articles pertaining to pre-Cambrian stratigraphy. Purely economic or petrological articles are not summarized unless they concern pre-Cambrian stratigraphy, in which case the substance of the conclusions is given, rather than a full account of the observations and the manner of reaching them.

The abstracts have the defects of all summaries,—a certain amount of inaccuracy, because many modifying and qualifying facts cannot be given, and because undue emphasis is placed upon the conclusions.

In many cases no comments are made. This does not imply that the editor agrees with the statements of the summaries. To criticise, qualify, or refute the statements of the authors in all cases of disagreement, would often result in extending the space taken by the comments beyond that required for the summaries. However, when the

points at issue are of general interest or of fundamental importance, is advisable to make comments and enter into discussions, even if t space taken by such comments be greater than that given to the su mary of the original articles. In such comments neither commend tion nor censure will be made, but the aim will be to point out t conclusions announced which fail of complete establishment and t generalizations which appear to go beyond what is warranted by t facts published. The purpose of indicating what appear to the edit as deficiencies of these kinds is neither to put himself dogmatically opposition to the statements of the author reviewed, but to dire attention to the questions involved, and in cases of doubt to keep the open for further study in the field and laboratory.

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Norian oder Ober-Laurentian von Canada. (Neues Jahrb., B. B. VI 1893, pp. 419–498.) Summarized Journ. of Geol., vol. 2, p. 110.

On the typical Laurentian area of Canada. (Journ. of Geol., vol. 1893, pp. 325–340.) Summarized Journ. of Geol., vol. 2, p. 111.

Preliminary report on the geology of a portion of central Ontario sit ated in the counties of Victoria, Peterborough, and Hastings, togeth with the results of an examination of certain ore deposits occurring the region. (Ann. Rept. Geol. Surv. of Canada, for 1892–3, vol. part J, pp. 15. 1895.) Summarized Journ. of Geol., vol. 3, p. 229.

A further contribution to our knowledge of the Laurentian (Art. VI (Am. Journ. of Sci., 3d ser., vol. 50, 1895, pp. 58–69. With plates and II.) Summarized Journ. of Geol., vol. 4, p. 364.

Laurentian area in the northwest corner of the Montreal sheet. Su plementary chapter to Ells' report on a portion of the Province Quebec. Ann. Rept. Geol. Surv. of Canada, for 1894, vol. 7, part pp. 93–112. 1896.) Summarized Journ. of Geol., vol. 6, p. 850.

Report on the geology of a portion of the Laurentian area lying to t north of the island of Montreal. (Ann. Rept. Geol. Surv. of Canad for 1895, vol. 8, part J, pp. 184. 1897. With geol. map.) Summa ized Journ. of Geol., vol. 7, p. 411.

——and BARLOW, A. E.

On the origin and relations of the Grenville and Hastings series in t Canadian Laurentian. (Am. Journ. Sci., 4th ser., vol. 3, 1897, p 173–180.) Summarized Journ. of Geol., vol. 7, p. 413.

AGUILERA, JOSÉ G.

Sinopsis de Geologia Mexicana. (Bol. del Inst. Geol. de Mexico, Num 4, 5, and 6, part 2, 1897, pp. 189–250. With geol. map.) Summa ized Journ. of Geol., vol. 7, p. 707.

AILEY, L. W.

Preliminary report on geological investigations in southwestern Nova Scotia. (Ann. Rept. Geol. Surv. of Canada, for 1892–3, vol. 6, part Q, pp. 21. 1895. With geol. map.) Summarized Journ. of Geol., vol. 4, p. 362.

Report on the geology of southwest Nova Scotia. (Ann. Rept. Geol. Surv. of Canada, for 1896, vol. 9, part M, pp. 154. 1898. With geol. map.) Summarized Journ. of Geol., vol. 7, p. 423.

ARLOW, A. E.

Relations of the Laurentian and Huronian on the north side of Lake Huron. (Am. Journ. of Sci., 3d ser., vol. 44, 1892, pp. 236–239.) Summarized Journ. of Geol., vol. 1, p. 308.

Relations of the Laurentian and Huronian rocks north of Lake Huron. (Bull. Geol. Soc. Am., vol. 4, 1893, pp. 313–332). Summarized Journ. of Geol., vol. 2, p. 114.

— and FERRIER, W. F.

On the relations and structure of certain granites and associated arkoses on Lake Temiscaming, Canada. (Geol. Mag., vol. 5, 1898, pp. 39–41.) Summarized Journ. of Geol., vol. 7, p. 419.

See Adams.

See Ells.

ASCOM, F.

The ancient volcanic rocks of South Mountain, Pennsylvania. (Bull. U. S. Geol. Surv., no. 136, 1896, pp. 124. With geol. map.) Summarized Journ. of Geol., vol. 6, p. 530.

AYLEY, W. S.

Actinolite-magnetite-schists from the Mesabé iron range in northeastern Minnesota. (Am. Journ. Sci., 3d ser., vol. 46, 1893, pp. 176–180.) Summarized Journ. of Geol., vol. 2, p. 454.

The eruptive and sedimentary rocks on Pigeon Point, Minnesota, and their contact phenomena. (Bull. U. S. Geol. Surv., no. 109, 1893, pp. 121. With geol. map.) Summarized Journ. of Geol., vol. 4, p. 750.

The basic massive rocks of the Lake Superior region. (Journ. of Geol., vol. 1, 1893, pp. 433–456; 587–596; 688–716; vol. 2, 1894, pp. 814–825; vol. 3. 1895, pp. 1–20.) Summarized Journ. of Geol., vol. 4, p. 751.

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On the Laurentian and Huronian systems north of Lake Huron. (First Rept. Bureau of Mines, Ontario, for 1891, pp. 63–94, 1892.) Summarized Journ. of Geol., vol. 1, p. 306.

Report on the Sudbury mining district. (Ann. Rept. Geol. Surv. Canada, for 1890–1, vol. 5, part F, pp. 95. 1893. With geol. ma Summarized Journ. of Geol., vol. 1, p. 539.

Pre-Paleozoic decay of crystalline rocks north of Lake Huron. (Bu Geol. Soc. Am., vol. 5, 1894, pp. 357–366.) Summarized Journ. Geol., vol. 3, p. 228.

Report on the geology of the French River sheet, Ontario. (Ann. Re of the Geol. Surv. of Canada, for 1896, vol. 9, part 1, pp. 1898. With geol. map.) Summarized Journ. of Geol., vol. p. 416.

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Geology of the St. Croix dalles. (Am. Geol., vol. 20, 1897, pp. 34 383, and vol. 21, 1898, pp. 139–155, 270–294.) Summarized Jour of Geol., vol. 7, p. 191.

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The spotted slates associated with the Sioux quartzite. (Johns Hopki Univ. Circulars, no. 121, 1895, p. 10.) Summarized Journ. of Geo vol. 4, p. 750.

The Sioux quartzite and certain associated rocks. (Iowa Geol. Sur vol. 6, 1896, pp. 69–112.) Summarized Journ. of Geol., vol. 7, p. 7

BLUE, A.

The new Ontario. (Fifth Rept. Bureau of Mines, Ontario, f 1895, pp. 193–196. 1896.) Summarized Journ. of Geol., vol. p. 751.

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The mode of occurrence of Eozoon Canadense at Côte St. Pierre. (Ge Mag., vol. 2, 1895, pp. 292–299.) Summarized Journ. of Geol., v 4, p. 363.

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Some dike features of the Gogebic iron range. (Trans. Am. Inst. Mi Engineers, vol. 27, 1898, pp. 556–563.) Summarized Journ. of Geo vol. 7, p. 190.

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Preliminary petrographic notes on some metamorphic rocks from easte Alabama. (Bull. Geol. Surv. of Alabama, no. 5, 1896, pp. 177–197 Summarized Journ. of Geol., vol. 6, p. 539.

See Wolff, J. E.

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Geology of the Waterloo quartzite area. (Trans. Wis. Acad. Sci., vol. 9 1893, pp. 255–274.) Summarized Journ. of Geol., vol. 2, p. 116.

URWASH, E. M.

Geology of the Nipissing-Algoma line. (Sixth Rept. Bureau of Mines, Ontario, for 1896, pp. 167–184. 1897.) Summarized Journ. of Geol., vol. 7, p. 419.

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The physical features of Maryland. (Maryland Geol. Surv., preliminary publication of vol. 1, 1897, part 3, pp. 95. With geol. map.) Summarized Journ. of Geol., vol. 6, p. 534.

Outline of present knowledge of the physical features of Maryland, embracing an account of the physiography, geology, and mineral resources. (Maryland Geol. Surv., vol. 1, 1897, part 3, pp. 139–228; Historical sketch, part 2, ibid., pp. 43–138. With geol. map.) Summarized Journ. of Geol., vol. 6, p. 535.

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The volcanics of the Michigamme district of Michigan (preliminary). (Journ. of Geol., vol. 3, 1895, pp. 801–822.) Summarized Journ. of Geol., vol. 4, p. 748.

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Clastic Huronian rocks of western Ontario. (Seventh Rept. Bureau of Mines, Ontario, for 1898, vol. 7, pp. 151–160. 1898.) Summarized Journ. of Geol., vol. 7, p. 201.

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General geology of the Cripple Creek district Ann. Rept. U. S. Geol. Surv., for 1894–5, pa Summarized Journ. of Geol., vol. 6, p. 848.

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Notes on the geology of Itasca county, Minn Ann. Rept. Geol. and Nat. Hist. Surv. of Mir 97–114. 1894.) Summarized Journ. of Geol

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Geology of Clinton county, New York (prelimir Rept. State Geol. of N. Y., for 1893, vol. 1, p also in Forty-seventh Ann. Rept. N. Y. State marized Journ. of Geol., vol. 6, p. 527.

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WRITERS CLASSIFIED BY REGIONS.

THE ORIGINAL LAURENTIAN AND HURONIAN AREAS (Eastern Ontario and Western Quebec).
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THE LAKE SUPERIOR REGION.
Bayley, Berkey, Blue, Boss, Clements, Coleman, Culver, Elftman, Finlay, Grant, Gresley, Hubbard, Lane, Lawson, Newett, Parks, Smith, W. H. C., Smyth, H. L., Spurr, Van Hise, Wadsworth, Winchell, N. H., Winchell, H. V., Winchell, A.

THE GREAT NORTHERN AREA OF CANADA.
Dawson, G. M., Dowling, Gibson, Low, McConnell, Tyrrell.

EASTERN CANADA AND NEWFOUNDLAND.
Bailey, Bonney, Dawson, G. M., Ells, Low, Matthew, Miller.

CANADA, GENERAL.
Dawson, G. M., Dawson, Sir Wm., Gibson.

THE NEW ENGLAND STATES.
Collie, Dale, Daly, Davis, Emerson, Hitchcock, Hovey, Sears, Whittle.

THE MIDDLE ATLANTIC STATES.
Bascom, Clark, Cushing, Darton, Grimsley, Hollick, Kemp, Keyes, Lesley, Marsters, Merrill, F. J. H., Merrill, G. P., Nason, Ries, Smyth, C. H., Westgate, White, Williams, G. H., Wolff.

THE SOUTHERN ATLANTIC STATES.
Clements, Darton, Hawes, Hayes, Keith, Kimball, King, Smith, E. A.

ISOLATED AREAS IN THE MISSISSIPPI VALLEY.
Beyer, Buell, Frazer, Hall, Haworth, Hill, Keyes, Nason, Norton, Osann, Sardeson, Todd, Weidman, Winslow.

THE CORDILLERAS.
Aguilera, Cross, Dawson, G. M., Eldridge, Emmons, Gilbert, Griswold, Hague, Iddings, Lakes, Lawson, Mills, Peale, Pirsson, Russell, Sapper, Walcott, Weed.

MEXICO AND CENTRAL AMERICA.
Aguilera, Sapper.

C. K. LEITH.

MADISON, WIS.

Reviews

The Upper Silurian fauna of the Rio Trombetas, State of Pará, Brazil. By JOHN M. CLARKE. *Archivos do Museu Nacional do Rio de Janeiro*, 1897–1899, Vol. X, 1–48. Rio de Janeiro, 1899.

Devonian mollusca of the State of Pará, Brazil. By JOHN M. CLARKE, *idem* 49–174.

These two papers are published in both English and Portuguese and are accompanied by eight beautifully drawn quarto plates, done by lithographers accustomed to work of this kind, illustrating all the species described.

The collections described are those made in 1876, in the Amazon valley, by the extinct "Commissão Geologica" or Imperial Geological Survey of Brazil. When the survey was suspended in 1877 the collections were turned over to the National Museum at Rio de Janeiro, and through the efforts of Professor O. A. Derby, previously a member of the survey and later director of the geological section of the National Museum, these unique collections were placed in the hands of Dr. John M. Clarke, one of our best American paleontologists. Dr. Clarke had already described and figured the trilobites of the Ereré and Maecurú sandstone, his paper appearing in Vol. IX of these same archives. The papers here mentioned make his second important contribution to our knowledge of the paleontology of the Amazon valley, and the most valuable since the publication of Dr. C. A. White's great work upon the Cretaceous fossils of Brazil.

At the end of the second paper he gives a list of the Devonian species of the Lower Amazon region, and finds the Ereré fauna to be "a miniature of the Hamilton" of New York (p. 158). The Curuá fauna he considers a member or modification of the Maecurú group. The rocks from which these fossils come are exceedingly rich, one locality, Ereré, furnishing forty-eight species, and, another, Maecurú, seventy-eight species.

In his summary concerning the Silurian fossils Dr. Clarke says that "the lower and upper Silurian elements of this little fauna are pretty equally commingled, and the inference is quite natural that in this

region the break in the record represented by the conventional plane of separation between the upper and lower divisions of the series is here obliterated. . . . . The little fauna is the oldest yet described from Brazil."

That last remark reminds me that some three years ago I published in this journal (Vol. IV, p. 975) a notice of an article by Dr. F. Katzer upon "The oldest fossiliferous beds of the Amazon region." In that article Dr. Katzer claims to have found graptolites in rocks said to have come from the Rio Maecurú region. Since the appearance of that note my attention has been directed to the fact that the article in question contained neither names, descriptions, nor figures of such graptolites, and that the origin of the fossils he mentioned was not really known—omissions that I should have observed without assistance.

It is a matter of painful interest to observe the great gaps of time between the collecting of the fossils by the Geological Commission, the date of Dr. Clarke's papers, and the date on the title page of this belated volume of excellent work.

We are accustomed in this country to hear more or less complaint about delay in the publication of government reports. But in this instance we may see if we will how much worse such matters might be. These collections were made in 1876, were placed in Dr. Clarke's hands in 18(?), the paper on the Silurian fossils was finished by him in 1891, that upon the Devonian in 1892, and the publication appears toward the end of 1899—twenty-three years after the field-work!

The inconvenience of this sort of thing is perhaps not as serious in Brazil where comparatively little is doing in science as it might be here or in Europe, but, like all other wrongs, sooner or later the country must pay for them. J. C. BRANNER.

The Cretaceous of the Black Hills as Indicated by the Fossil Plants. By LESTER F. WARD, with the Collaboration of Walter P. Jenney, William M. Fontaine, and F. H. Knowlton. Extract from the Nineteenth Annual Report of the U. S. Geol. Survey, Part II. Washington, D. C., 1899.

The results recorded in this extract are the outgrowth of a series of investigations beginning with the discovery of cycads in the Black Hills in 1893. From a study of these fossils and of their stratigraphical position, Professor Ward reached the conclusion that a part of the

›-called Dakota formation of the Black Hills belongs to the Lower 'retaceous series. This conclusion, together with the observations 'hich led up to it, he published in the JOURNAL OF GEOLOGY in the fol›wing year. Since that time the work of investigation has been reatly extended through the efforts of Professor Ward and his o-laborers, with the result that his former conclusion is now fully ubstantiated.

New fossil localities were found, and many new species were col:cted. Of the cycads, one hundred and twenty-six trunks and fragıents were examined. These were collected from two general although 'idely separated areas. The collection contains twenty-one species, ll of which are new to science. Fossil forests are mentioned as occuring at the same horizon.

Professor Jenney makes a report on the Hay Creek region, in which e finds: a marine Jura characterized by an abundant invertebrate ıuna; a later Jura resting unconformably upon the former, and charcterized by saurian bones and fossil wood; above this the Lower Cretaeous, which he subdivides as follows: (1) the Hay Creek formation; 2) the Barrett shales; (3) the Oak Creek beds. The series is characerized by an abundant flora which contains no cycads.

The flora of the region is described by Professor Fontaine, who ınds a number of species common to the Potomac formation, and a ew common to the Kootenai. This suggests a closer relation with the astern flora, but Mr. Ward thinks that this may not be the actual conlition, as the Kootenai flora has not been as thoroughly investigated s the Potomac.

A few outcrops of the "Atlantasaurus beds" are reported as occuring on the eastern flank of the Black Hills. These consist of clays repesenting a thickness of about fifty feet and containing bones of aurians. The beds are thought to have been laid down in the depresions of the eroded surface of the marine Jura. W. N. LOGAN.

The Geology and Physical Geography of Jamaica: Study of a Type of Antillean Development. By ROBERT T. HILL. Bulletin of the Museum of Comparative Zoölogy at Harvard College, Vol. XXXIV, 1899. pp. 256, 41 plates.

The general scope of this volume, which is an important addition :o the work which the author has heretofore done on Antillean geology,

is indicated by the title of the several parts of the volume. These a
as follows: Part I, Geography and Physiography; Part II, T
Geologic Structure and Sequence; Part III, Paleontology of t
Jamaican Sequence; Part IV, Relations of the Jamaican Formatio
to those of Adjacent Regions; Part VI, Changes of Physiography
Tropical America bearing upon the History of the West Indian Islan
Part VII, Appendices (1) Additional Note on the Geology of Porto Ri
and Santiago de Cuba, and (2) Some Cretaceous and Eocene Cor
of Jamaica (by T. Wayland Vaughan).

Geography.— Geographically the island is described as follow
There is a central mountain axis in the eastern third of the island, t
highest point of which is between 7000 and 8000 feet above sea lev
About this mountain axis, with its chief extension to the west, is
plateau ranging from 1000 or 1200 feet, to 3000 feet. The plateau
really a gentle arch, and its greatest elevation is in the central part
the island. The plateau terminates abruptly by steep slopes known
the "back coast border." The margins of the back coast border a
irregular, the result of valley excavation. The plateau is chiefly
limestone, and its interior topography is largely the result of soluti
and interior drainage. The plateau contains many remarkable basi
developed in this way. Some of them have no outlets, while oth
have recently been tapped by valleys working in from the margins
the plateau. The margins of the plateau are extensively terraced. (
the east side of Montego Bay there are at least six terraces, and wh
the number elsewhere is fewer, some of them are at levels considerab
above those shown at Montego Bay, so that the total number is mo
than six. The terraces are much interrupted by erosion, the oldest bei
least distinct, and most discontinuous. The highest occurs at elevatio
of 1800 or 2000 feet, an altitude quite above the top of the back coa
border in some parts of the island. The second highest terrace occu
at an elevation of about 1500 feet, the next at 1000 feet, and others
650, 300, and 200 feet respectively. The upper terraces appear to ha
been carved out of the limestone during the period of emergence whi
followed the deposition of the limestone. Those below 700 feet appe
to have been carved in a later period of elevation, following a perio
of submergence, after the higher terraces were made. The terrac
"have all been cut out of the land by gradational processes (base leve
ing and marine erosion) and represent pausation stages in two lon
periods of elevation" (p. 33).

If the back coast border of the plateau were continued seaward, the borders of the island would lie much beyond the present shore line, and from this and other phenomena it is inferred that the former extension of the island was considerably greater than the present. There are terraces on the submerged slopes of the island similar to those above the water, which are in harmony with this view.

Bordering the plateau below the back coast border there is a coastal plain which is nearly continuous. In some places it is narrow, and in others it reaches far back into the island. The coastal plain is made up of three sorts of formations, elevated reefs, sea margin débris, and land alluvium. The coastal plain is more or less terraced by old wave-cut terraces, which have since been submerged and are now veneered with later deposits. The highest is about 150 feet above sea level. Elevated reefs occur at three levels, 60, 25, and 15 feet or less, respectively, above sea level.

The streams of the island belong to two types: (1) the autogenous type, with the peculiarities which go with changes of level; and (2) the interior streams which drain into limestone sinks. In addition to these two types, there is a combination type which results from the capture of the interior drainage by streams which flow seaward.

A topographic map with 250-foot contours and a geologic map accompany the volume, and help to make the geography and geology clear.

Geology.—The central mountain axis of the island is made up of rocks known as the Blue Mountain series. This series is made up chiefly of "loose or slightly indurated beds of gravel, clay, bowlders, and tuffs, with exceptional beds or bosses of hard indurated limestones and yellow clay. The rocks are usually of dark color . . . . in strong contrast to the glaringly light colors which characterize the succeeding formations of the oceanic and coastal series. The material, with the exception of occasional limestone beds and a few outcrops of clay marls, can be traced to igneous rocks; it was first volcanic ejecta and subsequently and successively underwent various degrees of attrition and sedimentation" . . . . (p. 41).

This Blue Mountain series constitutes the surface formation of all parts of the island which rise above 3000 feet. From exposures at lower levels where erosion has removed the overlying strata, it is known that the same series has extensive development beneath the younger formations, and from the known exposures the series is believed to

underlie most of the island. The beds of the are much deformed. Since a continuous expo is nowhere found, exact measures of thick obtained, but it is stated that the thickness p feet.

The Blue Mountain series is made up of Lower Eocene beds. There seems at this point in the classification, since the Richmond forma be the upper part of the Blue Mountain series, i some points (geological map), but as Upper C 143). The Blue Mountain series is exposed in t parts of the island at levels which are below the In these localities, erosion has removed the over

The Blue Mountain series is overlaid by the a formation not extensively exposed. Where older series. It is made up of clays, marls, a and occupies a transitional position between material of which was derived from land forr succeeding formation, the material of which is li of oceanic origin. The Cambridge formatior Eocene.

The Cambridge formation is followed in str extensive formation of White Limestone, the prin plateau. It has by far the widest surface devel tion on the island. It covers the whole of the i of the plateau (3000 feet) and the coastal plai portions of the latter. In the western part of th covers (or once did) the Blue Mountain series. are often considerably disturbed. The formati water origin, since it contains neither reef co Its fossils are mainly microscopic, and it is refer of the Oligocene period.

The formations of the island younger than belong to the coastal series, and were made af affected the island. These coastal formations sorts of rock: (1) marine beds, (2) alluvium, (3 and (4) littoral deposits.

The oldest of these formations is known as t the age of which seems to be in some doubt. I

ıte Oligocene or Miocene. The formation was deposited after a subidence which followed the uplift and extensive erosion of the White ,imestone. The break between it and the White Limestone is, there›re, a great one, and on general grounds it would seem more in ccord with modern classification to make the break between these two ›rmations the division between the Oligocene and Miocene than to lace it in the Oligocene. The Bowden formation has a thickness of omething like 250 feet. Its outcrop consists of a fringe around the lder plateau region, and it is, in turn, bordered by still later and ›wer-lying formations. The Bowden formation is made up of various ›rts of sedimentary rock.

The next succeeding formations are classed as Pliocene. They are omposed of marl and limestone of marine origin (Manchioneal), and f slight thickness, and of gravels from the uplands. The gravels are, ı part estuarine, in part subaërial, and in part littoral. The Pliocene ›rmations have relatively slight surface development, though considerble areas in the vicinity of Kingston are covered by them.

Among the Pleistocene formations are beds of reef rock, ten to ›rty feet in thickness. They range in elevation from sea level up to :venty feet. They lie on eroded land surfaces, and their relations re significant of the movements to which the land had been subject efore their formation. Other Pleistocene formations consist of chalky ıarls at low levels near the coast. Here belongs especially the Falıouth formation which rarely occurs higher than fifteen feet above the :a. The Falmouth formation is nothing more than a series of unconolidated sea muds, probably synchronous with the younger elevated oral reefs. Among the latest formations are the alluvial deposits in alleys about the shores. In Montego Bay there are low islands which we their origin primarily to mangroves.

There are some igneous rocks on the island. The oldest are the owlders of andesite in the Blue Mountain series. The source of this ;neous matter is unknown. There are mid-Tertiary igneous rocks in ıe form of dikes, laccoliths, etc., composed of hornblende-diorite, and ranite-porphyry. These intrusive rocks affect the Blue Mountain :ries, and extend upward into the White Limestone above, but re found only in the eastern third of the island. In a single locality n the north coast near the east end of the island there is eruptive mygdaloidal basalt. There is everywhere more or less metamorphism ı association with the igneous rocks.

The topography and stratigraphy of the island suggest the follo ing sequence of events :

1. The first event in the history of the island so far as now kno is the igneous activity which furnished the material for the B Mountain series. This was probably in Cretaceous time. The old formation of the island is composed of the débris of this activity. T amount of the débris was great, indicating that the volcanic activ was extensive.

2. The degradation of the volcanic débris and the re-deposition the material in the form of sedimentary formations (the Blue Mount series) was the second great event in the history of the island. T formation is such as to show (*a*) that there was rapid erosion a deposition ; (*b*) that the land from which the sediments came high ; and (*c*) that the deposition was accomplished in shallow wa

3. The next event was the elevation, and, perhaps, the folding, the beds of the Blue Mountain series. The folding probably follow the deposition of the Richmond (Eocene) formation ; that is, was m Eocene. On this point, however, the author is not altogether satisfi and indicates that the folding may possibly have occurred later.

4. The next event was the sinking of the island, probably late the Eocene period, followed by the deposition on the submerged surf of the great White Limestone formation. The subsidence is estima to have been at least 1200 fathoms. This great subsidence submerg all but the higher parts of the Blue Mountain series, leaving at m only the parts which are now more than 3000 feet high out of wat The subsidence may have been even greater, submerging the wh island. The evidence of this great subsidence is found in the Mo pelier chalk (the lower part of the White Limestone), the compositi of which indicates, according to Mr. Hill, a depth of 1200 to 23 fathoms. Further evidence of the great subsidence is found in t stratigraphically equivalent radiolarian earths in eastern Cuba—eart which call for depths of 3000 to 4000 fathoms. Mr. Hill thinks would not be unfair to assume 10,000 feet as the mean subsidence Jamaica (p. 165). The argument of Mr. Hill for so great a sinki does not seem altogether conclusive. If the whole of the island we submerged, and this would not seem to call for so great a subsiden (though still a great one) there is no apparent reason why formatio due to pelagic life should not be made in shallow water, even thou too deep for corals and other shore-life. A few hundred feet of wat

d destroy these shallow water forms, and since there would be no :e for terrigenous material, the shells of pelagic life should have the chief source of sediment. The problem is the same as that :nted by the Niobrara chalk of the United States. It shows ıce of terrigenous sediment rather than great depth of water.

. The next event in the history of Jamaica was the re-elevation of sland in the Oligocene period. The amount of elevation is esti- d at 13,000 feet. If the preceding subsidence were less than stated e, the call for so great a rise would disappear. After this re-eleva- the island is believed to have had a much larger area than now. uplift was accompanied by a gentle folding of the rock, the ng having an east-west axis, and therefore making an angle with .xes of the older mountains, the trend of which is northwest and ıeast. With the general arching of this time there were many ›r folds. It is believed to have been in connection with this ele- n that the igneous intrusions of mid-Tertiary time were effected, :he higher terraces on the margins of the plateau developed.

. The next event was another subsidence, contracting the island to ›ack coast border. The depression is placed at about 3000 feet. It ıt this time (as well as during the preceding interval of emergence) the back coast border of the plateau was developed. During this ›r submergence the Bowden formation (Miocene), reaching up to s of 300 feet, was deposited.

. This subsidence was followed by an elevation. The Blue ntain ridges and the plateau were elevated some 500 feet. The ers must have been elevated much more, for the southern coast is :ved to have been extended out to about the present 500-fathom This movement of elevation was less orogenic in its character any of the preceding, and was followed by a period of erosion. ing the pre-Bowden epoch of erosion the streams did not get their ls far back into the plateau, but developed great amphitheaters the edge of the back coast border, while great basins were being :loped in the interior. During the post-Bowden interval of erosion, :oast streams worked back, and drained out many of these interior ns. It was during this elevation that the middle terraces, of the : coast border — those at elevations of 200 to 700 feet — were :loped.

3. The next event was probably a late Pliocene subsidence of not : than 700 feet. This submerged the border of the island to the

base of the back coast border, covering the present low borders wi
littoral and estuarine formations.

9. The next and last event was an epeirogenic movement of upwa
phase, amounting to about 800 feet, which raised the submerged bo
ders into the present coastal plain. This upward movement may ha
been interrupted by a minor subsidence, in early Pleistocene times.

There were, therefore, according to this interpretation four distin
periods of subsidence after the deposition of the Blue Mountian seri
(*a*) The subsidence which preceded the deposition of the Montpeli
(Oligocene) formation; (*b*) the subsidence which preceded the depo
tion of the Bowden (Miocene) formation; (*c*) the subsidence whi
prepared the way for the Manchioneal (Pliocene) formation, and (*d*) t
subsidence which resulted in the deposition of the Pleistocene mari
formations within the present land area. These four subsidences alt
nated with corresponding elevations: the first in the mid-Oligoce
period, elevating the White Limestone; the second in the late Miocen
lifting the Bowden formation; the third in the early Pleistocen
bringing up the Pliocene formation; and the latest, exposing the mari
Pleistocene. This series of uplifts and depressions constituted a dimi
ishing series, being in this respect in consonance with other Antille
and with mid-American phenomena. The post-Richmond (ea
Eocene), the post-Moneague (mid-Oligocene, White Limestone), a
post-Bowden (Miocene) uplifts were orogenic, diminishing, howev
in their orogenicity.

In that part of the volume which deals with the relations of t
Jamaican formations to those of adjacent regions, the author announ
the general conclusion that the Jamaican sequence is very like that
the other islands of the Great Antilles.

In his summary of the history of the Antillean region the follo
ing generalizations are given:

1. The geology and configuration present no evidence whatsoe
whereby past land connections can be established between these islands a
the North and South American lands in Post-Jurassic time, especially in t
Tertiary, Pleistocene, or recent epochs.

2. The configuration and condition of these islands in pre-Jurassic ti
cannot even be surmised.

3. There are some hypothetical and biologic reasons for believing th
the outer rim of the American Mediterranean constituted a partial or co
plete bridge between the continents in Jurassic time, and that the Panar
bridge did not then exist.

4. The first definite evidence of Antillean lands is found in the eruptive rocks of late Cretaceous time, when it is probable that there were marine volcanoes.

5. The land débris constituting the Eocene strata throughout the islands testifies the pre-existence of extensive Cretaceous land areas.

6. There was a profound regional subsidence in late Eocene and early Oligocene time, which submerged all but the highest tips of the Antilles, and which extended to the margins of the surrounding continents.

7. In late Oligocene or Miocene time there was a tremendous oroganic movement which resulted in uplift, whereby many of the islands were connected with each other, and possibly an insular southern portion of Florida, but not establishing land connection with the North and South American continents.

8. In Miocene or early Pliocene time the islands were severed by submergence into their present outlines and membership, which they have since retained with only secondary modification.

9. In Pliocene and Pleistocene time there have been intermittent periods of elevation without serious deformation, but not sufficient to establish land connections or to restore the islands to the heights and areas of mid-Tertiary time. The Pleistocene movements, while epeirogenic, were sufficiently differential to show that they were not uniform in all parts of the area, showing great differences in amplitude within the West Indian area, and were not harmonious with those of the North American coastal plain.

10. The irregularities of the submerged configuration of the West Indian region are orogenic, and not due to submerged continental drainage systems.

11. The elevated coral reefs of the West Indies were formed on rising lands.

In appendices Mr. Hill gives an additional note on the Geology of Porto Rico and Santiago de Cuba, and Mr. T. Wayland Vaughan describes some Cretaceous and Eocene corals from Jamaica. The note on the geology of Porto Rico and Santiago de Cuba, based on a recent geological reconnoissance, is as follows:

1. An older plexus of water-sorted hornblendic volcanic material—tuffs and conglomerates with interbedded Cretaceous Rudistean limestone similar to that of Jamaica, composing the central mountains.

2. An Eocene system of impure lignitic sands and clays like the Richmond beds, occurring on the western side of the island near San Sebastian.

3. Fossiliferous marl beds overlapping the above, which at this writing have not been determined.

4. Miocene coral limestone, unlike anything hitherto recorded from the Great Antilles, but of the type occurring in Antigua. These constitute the hilly country north and northwest of Lares.

5. White limestones of probable Pliocene age, co
south coast.

6. Elevated reefs, but feebly represented.

7. Alluvial plains of Pleistocene age. The terr
developed upon this island than in any of the other
the Pleistocene base leveling is well developed in str
Dikes of syenitic-like porphyry, probably diorites, w
the older hornblendic rocks.

Evidence was obtained indicating that the grea
culminated before the Miocene, and that there has bee
feet of vertical uplift since that epoch.

The recent work in Cuba consists of a sect
Maestra from the coast to the Rio Cauto. In ma
Hill was convinced "that the crystalline rocks o
taceous and post-Eocene Tertiary, and not Pal
Frazer. . . ."

Die Stillstandslagen des letzten Inlandeises und
Entwickelung des pommerschen Küstenge
KEILHACK. Separatabdruck aus dem J
preuss. geologischen Landesanstalt für
90–152, 14 plates.

The immediate object of this paper is to se
between the edge of the ice and the drainage o
ing the last glacial epoch. The general slope of so
ward, and the general slope of the ice which lay
was southward. Along the meeting of these c
courses were developed while the ice was in exis
marginal water courses were lakes, but often ther
along them. Many of the peculiarities of topo
date from the time of ice occupancy.

Incidentally, several points of general interes
Keilhack recognizes three distinct glacial epochs.
recognizes five more or less distinct stages of the
the maximum advance of this epoch, and the oth
Each of these stages had its marginal water cour

During its maximum stage the limit of the ice
north of the Malapane and Oder rivers, as far

ɜnd of the latter, southeast of Glogau. From this point west the lge of the ice was south of the Oder, having a general west-orthwest course to Magdeburg. West of Magdeburg the position of ıe edge of the ice has not been determined. It was perhaps along the .ller River, and perhaps farther north along the divide between this ver and the Elbe. During this stage of the ice marginal drainage as westward along the valley of the Malapane to the junction of that .ream with the Oder at Oppeln, thence down the Oder to Breslau and eyond. Here the drainage left the present course of the Oder vhich beyond this point was buried by the ice) and flowed west-orthwest to the valley of the schwarze Elster, thence along that alley to the Elbe, and down the Elbe to its junction with the aale.

The halting places of the ice during its retreat are recognized by ıree principal criteria. First, the *endmoräne*, which are bowlder walls ıs that term is used by the Germans); second, the great ridge-belts of ıarkedly undulatory topography regarded as terminal moraines in the Inited States; and third, the sand and gravel plains outside the ridges ıst referred to. All these criteria are found in connection with the dge of the ice at its various stages, but in better development in some ases than in others.

The edge of the ice during the first recognized halt in its retreat ıy a few miles farther north, running in the same general direction. Roughly, it extended from Pleschen to Potsdam, and thence to a oint near Lauenburg just north of the Elbe. West of Lauenburg the order has not been traced. The margin of the ice during this halt ʼas more or less lobate. The marginal drainage was along the Bartsch-Baruth Valley to the Elbe north of Magdeburg. Farther west the ourse of the drainage is uncertain.

The second halt of the ice, marking the third position of a more or ɜss stationary edge, lies still farther north, along the divide between he Warthe and the Netze from longitude 36° E. to Frankfurt on the)der. Here the edge of the ice crossed the present course of the)der, and extended westward and northwestward to Schwerin and ›eyond. During this stage the marginal drainage was westward along he course of the Warthe to the longitude of Posen, thence westward o the Oder and down the latter nearly to Frankfurt, thence westward ›y way of the Spree to Berlin, and thence west-northwest to the Elbe, .nd thence to the North Sea.

The third halt in the ice front shows that the recession was v unequal in different regions. In the eastern part of Germany the ed of the ice at this stage was far north of its position during the prec ing stage, while in west Germany the differences in position w slight. Generally speaking, the border of the ice between the Weich and the Oder, lay along the divide between the Netze on the sou and the drainage which flows directly to the Baltic on the north. crossed the Oder near Oderberg; thence it ran in a general northw direction to Lübeck. From Lübeck it extended north-northw through Jutland. During this halt the edge of the ice had two possibly three great lobes. The greatest of these lay between Dan on the east and Lübeck on the west. East of Danzig there was anot lobe extending well southward, the eastern limit of which is mapped. West of Lübeck the Jutland ice may be regarded as co stituting a third lobe. Beside these great lobes, there were ma minor crenations of the edge. This stationary position of the ice is best known of all, partly because it has been more studied, and par because it is far more distinct. All the criteria of the stationary ed find here their best development. The morainic (as that term is us in America) belt of this stage is the Baltic *Höhenrücken*. It is t belt which the reviewer traced out in a rough way in 1887, and ch acterized as the great terminal moraine of north Germany.[1] Dr. Ke hack says that this moraine is bordered throughout 650 of the 7 kilometers of its length in Germany by sand plains. The morai topography of this belt is much more strongly developed than that the other halting places, as also the *Endmoräne*. To Dr. Keilhac conclusion that the ice along the fourteenth part of this 700 kilomet where sand plants are absent, disappeared chiefly by evaporati instead of by melting, we can hardly subscribe.

During this stage of the ice the marginal drainage was along t Thorn-Eberswalde Valley which connects with the Elbe southeast Wittenberge. Along this course the water was partly fluviatile a partly lacustrine.

The fourth and last chief halting place recognized is near t Baltic. In receding to this position from the last the ice retreat most over the lowest ground, and least over the highest. A new ma ginal drainage line was formed not far from the coast, and rough

[1] Terminal Moraines in North Germany, Am. Jour. Sci., Vol. XXXV, Series pp. 401.

ırallel to it from Danzig to Stettin, and thence *via* the Trebel to the altic near Ribnitz. Some parts of this marginal water course were ıviatile and some lacustrine, the largest lake being about Stettin. hese lakes are described in detail. For the largest three distinct ·vels are made out, the highest of which is 25 meters above sea level. hese stages are connected with the retreat of the ice, and the openıg of new outlets. The development of the present Baltic drainage described in great detail. Many of the north-south valley now raining to the Baltic are thought to have been originally subglacial ılleys draining south to the marginal valley last mentioned before ıe ice melted away. The drainage through them was then reversed.

Between the fourth halting place of the ice and the Baltic Sea .eilhack makes out and maps eleven substages in the recession of the e, each changing in some recognizable way, the drainage of the pre:ding stage. These subordinate stages, like the larger ones, show ıat the ice did not retreat at the same rate all along its front. So etailed a piece of work concerning drainage along the margin of the e has not before been published.

One of the interesting facts brought out in this paper is the simi.rity of the phenomena of the last glacial epoch in Germany with ıose of the corresponding epoch in the United States. In the Wis-ɔnsin epoch the edge of the ice made several halts in its recession om its position of maximum advance. In each of these positions ıorainic belts were developed, and as in Germany the strongest of ıese belts was not at the position of maximum advance, but in a more ortherly position. As in Germany, each morainic belt is bordered by ınd plains. As in Germany, the recession of the edge was unequal, ad here as there, the lobations of one stage did not correspond with ıose of another. The analogies might be carried much further, but ot to the drainage from the ice, since similar topographic relations id not exist in the United States.

R. D. S.

'hore Line Topography. By F. P. GULLIVER. Proc. Am. Acad. of Arts and Sciences, Jan. 1899. pp. 151–258.

In this essay Mr. Gulliver presents the mature results of a very :rious piece of work. The topography of shore lines is considered nder *initial* forms and *sequential* forms. Under initial forms are

included those which shore action has not modified since the reg concerned was uplifted or depressed (relative to the surface of the s Under sequential forms are included those features which are de oped subsequent to the diastrophic change, by the forces at w along the shore. The larger part of the essay is naturally devotec sequential forms.

The reading of this essay makes several things evident. In first place, Mr. Gulliver has exhausted the literature on the subj with which he deals; and, in the second place, he has made dilig use of maps. In the use of this material he has gathered a large b of facts which he has attempted to interpret and classify. Not o this, but he has attempted to interpret and classify them *in terms development*, so as to put the topography of shore lines on an eq footing with the topography of land surfaces, as an index of g graphic evolution. So far as we are aware, this is the first ti this task has been essayed, and the author is to be congratulated the successful outcome of his study. Geography and geology are gainers, and the future student of coast lines will hardly fail to cons this essay.

In the author's own words, the thesis of the essay is the followi "The forms of any coastal belt may be grouped in the appropri stages of a cycle. These forms will be consistently related to associated land area on the one hand, and to the sea bottom on other. When considered together, the forms of a coastal belt indic the relative time since the last considerable uplift or depression well as the ratio existing between the several activities, in th dynamic effect upon the forms of the coast and the shore." whole essay is the expansion of this idea.

In consonance with this mode of treatment of the subject, author has made use of many of the life terms, such as infancy, you adolescence, maturity, etc., which are now in use in connection w the history of rivers. Some of these terms have a new meaning wh applied to coast lines, and their adoption will be at the cost of so mental effort. At the outset it will be necessary to stop to think wh the terms mean in connection with coast lines, as distinct from wh they mean when applied to land surfaces in general. This, howev is no serious objection to their use. On the first reading of the ess it must be confessed that the use of biological terms sometimes seen a little forced. Such objections as may be entered to their use will

ged to old-fogyism by those who like to see the old terms used in new way, and to conservatism by others. The reviewer is pre- d to go a good ways in the application of biological terms to geo- ›hic evolution, where the terms fit, but when a large and quickly : delta is called a "precocious infant" (p. 224), it seems to be ,g a trifle far. Such criticism is, however, on the surface of things; ›uches nothing fundamental. Some new terms are introduced to gnate forms which have been nameless, and some of them are so 1 and so much needed that they should be adopted at once. An nple is "wave-base" (p. 176) to denote the plane to which waves degrade the bottom in shallow water. It is the correlative of level. Some other terms, however, do not at first seem so neces- or so happily chosen. To this class belongs "winged beheadland" enote a sea cliff with a spit on either side (p. 213).

There are not a few minor points in the essay which might be cised, but it seems almost ungracious to mention them in the ence of so many larger matters which deserve hearty commenda- . Glacial erosion seems not to have due recognition among the ıcies which shape shore lines. It is true that the author expressly laims his intention of discussing this point, and it is true that ial modification of coasts are accidental, in the sense of not being rt of the normal cycle which is the theme under discussion, but it ıt have been well to recognize more fully the effects of glaciation onnection with some of the coasts referred to, even though the ect of glacial modification of coast lines is not discussed. The ərs on Lake Agassiz are gently criticised for describing the shore ; of that lake as if they "were formed once for all and would ver remain as constructed" (p. 187), but the truth is, these shore ; are still sensibly as constructed, and no one has essayed to write he history of the changes which these shores will yet undergo. It be readily seen that when such minor points are the things which ;est themselves for criticism the essay as a whole is strong.

Not only is the essay a serious piece of work, as suggested at the et, but, by means of the numerous references, both cartographic textual, the author has placed the material on which he based his :lusions at the command of future students. From this material ents may draw their own conclusions, and, judging from the tone he essay, no one would be more ready to entertain alternative :lusions than Mr. Gulliver himself. R. D. S.

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